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Vanderbilt Audiology Journal Club: A Vestibular Update

Gary Jacobson, PhD
Richard A. Roberts, PhD
Kelsey Hatton, AuD

Learning Outcomes

After this course, participants will be able to:

- List recent key journal articles on the topic of vestibular that have implications for audiology clinical practice.
- Describe the findings from recent key journal articles on the topic of vestibular that have implications for audiology clinical practice.
- Explain the implications for audiology clinical practice from recent key journal articles on the topic of vestibular.
“The Dizziness Symptom Profile - DSP”
Development and Preliminary Observations

Gary P. Jacobson, Ph.D.
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Development and Preliminary Findings of the Dizziness Symptom Profile

Gary P. Jacobson,1 Erin G. Piker,2 Kelsey Hatton,1 Kenneth E. Watford,1 Timothy Trone,1
Devin L. McCaslin,4 Marc L. Bennett,3 Alejandro Rivas,3 David S. Haynes,3
and Richard A. Roberts1
The Problem:

Too many dizzy patients and not enough specialists to diagnose and treat them correctly

Background: How many?
Dizziness, vertigo, chronic unsteadiness is common

- It is estimated that up to 69 million Americans have experienced symptoms of a vestibular disorder
- ~8 million Americans experience chronic imbalance
- ~2.4 million Americans experience chronic dizziness
- Of people ≥ 65 years of age ~50% have experienced BPPV
- Of patients referred for falls risk assessment
  - ~75% have been identified with an undiagnosed vestibular system impairment (Jacobson et al.)
Background

Dizziness and Primary Care

• Dizziness is the presenting complaint of 2.5% of patients who are evaluated by primary care providers (PCPs).
  – 45% of dizzy patients are evaluated initially by PCPs.

• Problem: PCPs have little expertise in the neurotological assessment and treatment of dizziness and vertigo.

• However, some dizziness disorders could be managed by PCPs e.g.: Persistent, postural-perceptual dizziness (PPPD), Vestibular migraine (VM), Benign Paroxysmal Positional Vertigo (BPPV).

The problem

• Despite the millions of dizzy patients seeking medical help:
  – There are 7,659-10,000 practicing otolaryngologists in the USA (Vrabec, 2013, Diana Harrell – American Board of Otolaryngology, personal communication).
  – There are only ~323 practicing neurologists, (http://www.dizziness-and-balance.com/default.html) and,
  – There are only ~42-50 practicing oto-neurologists in the USA (http://robbmd.com/personal communication, T.C. Hain, M.D., personal communication),
  – There are ~50 practicing neuro-opthalmologists.
The problem

- There is a lack of specialty care providers who can assess patients who have the complaints of vertigo, dizziness and/or unsteadiness.
- Since we have no control over the number of specialty providers...
  - ...one possible solution would be to diagnose correctly, and manage earlier, dizzy patients who present to primary care, or general OTO.

Case History Taking

- Must obtain salient bits of information in a short period of time.
- Case history enables the clinician to generate hypotheses about the underlying disease responsible for the patient’s complaints.
- Hypotheses are supported, or rejected, based on evaluation, electro-neurodiagnostic data, and neuro-imaging.
Case History Taking

- However, case history taking can be frustrating
- Patients may:
  - complicate even structured case histories by volunteering information that does not contribute to the diagnosis…
  - …may feel slighted if not given sufficient time with the clinician

One Solution…

- Develop a case history device that incorporates standardized diagnostic criteria
- No open-ended questions
- Would be developed by “dizziness experts”
- Could help healthcare providers (HCP) create a “differential diagnosis.”*
- Then HCP conducts their H&P to determine whether they agree with the case history device.

* DD = Diagnoses other than the one that is finally established, which the doctor may consider depending on the symptoms presented by the patient.
For example

- **If the result** of the questionnaire **pointed to BPPV** …
  - the primary care provider could then conduct Dix-Hallpike, or **head-roll** maneuvers to determine if posterior or horizontal SCC canalithiasis existed.
  - Where pSCC BPPV or, hSCC BPPV existed the provider could administer the appropriate repositioning maneuver and “cure” the patient

For example

- **Where the result** of the case history device **pointed to vestibular migraine**…
  - The provider could place the patient on a **migraine diet**, or,
  - **Begin prophylactic pharmacological treatment**
Alternately

- Where the result of the questionnaire suggested the presence of vestibular neuritis, labyrinthitis, Meniere’s Syndrome, or, superior semicircular canal dehiscence
  - The patient would be referred directly to specialty/subspecialty care (i.e. otology/neurotology) for assessment and management

Net sum

- Even if the patient was not initially examined and managed by a dizziness expert...
- ...they could be evaluated against diagnostic criteria developed by dizziness experts
- Initial management could be driven by “care pathways” developed by the experts.
Purpose of the DSP

- **Not to** “diagnose” disease
- **Not to** replace the ear specialist
- **To** provide clinicians with a tool to help them focus their case history efforts on areas identified by the DSP
- **To** help create the “differential diagnosis”

35,000 ft Methods

- Create items where symptom description is sensitive to each of the target diseases
- Randomize and place them on a response form
- Administer it
- Do a statistic that identifies patterns in the responses to the items (PCA exploratory analysis)
- Name the patterns (e.g. BPPV, Meniere’s d. etc)
- Eliminate items that do not contribute
- Randomize and re-administer
- Re-do the statistics that identify patterns of response (PCA confirmatory analysis) determine stability
Investigation 1
Initial tool development

- 64 items
- Content of items based on:
  - Accepted diagnostic criteria (e.g. vestibular neuritis and labyrinthitis)
  - Guidelines and consensus statements (e.g. BPPV, vestibular migraine, Meniere’s disease)
  - Expert opinion (SCD), and,
  - Empirical observations during case history taking by the two senior investigators and senior otology staff

Instead of asking a series of case history questions and waiting for a response that may or may not address the question, we created a series of statements:

- “There are times when I get dizzy and also have a headache.”
- The patient responded to each statement with a 0-4 response on a 5 point Likert scale with 0 = strongly disagree, 2 = neutral, 4 = strongly agree
- Representative items follow…
Sample Items

- There are times when I get dizzy and also have a headache. (Vestibular migraine)
- I have a roaring sound in one ear only before or during a dizziness attack. (Meniere's syndrome)
- I have had constant dizziness for more than 3 months. (PPPD)
- I can hear my eyes move. (SSCD)
- My dizziness is intense but lasts for seconds to minutes. (BPPV)
- I had a spell of spinning dizziness that lasted for days or weeks after I had a cold or flu. (Neuritis labyrinthitis)
- I have a tingling sensation in my feet. (Multisensory system impairment)

Investigation 1

- For each item the subject's response not only represented both an endorsement (or lack thereof) but also the strength of the endorsement.
- The items were randomized on the data collection form
- N = 162 (mean age 55 yrs, 57 male)
Investigation 1

- The instructions were:
  - "The following pages contain statements with which you can agree or disagree. For each item please indicate to what extent you agree or disagree with regards to your dizziness. Use the following scale: 0 = strongly disagree, 1 = disagree, 2 = not sure, 3 = agree, 4 = strongly agree. Please circle the number that best describes your dizziness. Please complete all of the items"
Phase 1 64 item DSI, randomized, subject response form

Principle Components Analysis (PCA) enables us to determine whether individual items (variables) we have created can be reduced to a smaller set of latent variables or components.

Component "load" tells us how much each item correlates with each component.
Component 1 – Vestibular Migraine

- Item 53: I get headaches that hurt so badly that I am completely unable to do my daily activities
- Item 33: When I get a headache I am very sensitive to light (I try to find a dark room to rest.)
- Item 57: Members of my family get migraine headaches.
- Item 16: I have had severe headaches in the past.
- Item 38: When I get a headache I am very sensitive to sound (I try to find a quiet place to rest)
- Item 46: My vision changes before a headache begins
- Item 1: There are times when I get dizzy and also have a headache

Component 2 - Meniere's d.

- Item 12: I have a roaring in one ear only before or during a dizziness attack
- Item 47: I lost hearing in one ear after an attack of spinning dizziness
- Item 40: My hearing gets worse in one ear before or during a dizziness attack
- Item 44: I hear my voice more loudly in one ear compared to the other
- Item 27: I have a feeling of fullness or pressure in one ear before or during a dizziness attack
Component 3 - SCD

- Item 50: I get dizzy when I sneeze.
- Item 55: When I cough I get dizzy.
- Item 22: Loud sounds make my vision blurry.
- Item 26: Loud sounds make me dizzy.
- Item 8: I get dizzy when I strain to lift something heavy.

Component 4 - Vestibular neuritis

- Item 52: I have had a single severe spell of spinning dizziness that lasted days or weeks.
- Item 60: I had a single constant spell of spinning dizziness that lasted longer than 2-3 days.
- Item 35: I had a big dizzy spell that lasted for days where I could not walk without falling over.
- Item 2: I had a spell of spinning dizziness that lasted for days or weeks after I had a cold or flu.
Component 5 - BPPV

- Item 56: I get short-lasting, spinning dizziness that happens when I go from sitting to lying down.
- Item: 37: I get dizzy when I turn over in bed.
- Item 11: My dizziness is intense but only lasts for seconds to minutes.
- Item 17: I can trigger a dizzy spell by placing my head in a certain position.
- Item 48: I get short-lasting, spinning dizziness that happens when I bend forward to pick something up.

Component 6 - Persistent, postural, perceptual dizziness - PPPD

- Item 14: I have spells where I get dizzy and it is difficult for me to breathe.
- Item 59: I get dizzy spells where I also feel like I have a lump in my throat.
- Item 4: I get dizzy spells where I get dizzy and also have irregular heart beats (palpitations)
- Item 24: I am depressed much of the time
- Item 61: I am anxious much of the time
Component 7 - Unsteadiness (utricular?)

- Item 58: I am unsteady on my feet all the time.
- Item 3: I am unsure of my footing when I walk outside.
- Item 21: I get dizzy when I am in open spaces and have nothing to hold on to.
- Item 32: I have a sensation of dizziness or imbalance daily or almost daily.

Phase 2
Stability of the PCA
Phase 3 DSP
(DSP is reduced to 31 items)

Is there agreement between the differential diagnosis generated by the DSP and the differential diagnosis generated by the “gold-standard” (ear specialist) following their H&P?

Data Collection Sheet to be Completed by the Patients:

The Dizziness Symptom Inventory

The following list of symptoms may be experienced during or after a dizziness attack. Please check all that apply:

1. My dizziness is worse on one side or in one ear.
2. I have a feeling of spinning or swaying.
3. I have a head lightheaded or dizzy.
4. I feel like I am about to fall or lose balance.
5. I feel dizzy when I get up quickly.
6. I feel dizzy when I bend over or lean forward.
7. I feel dizzy when I stand up or sit down.
8. I feel dizzy when I move suddenly.
9. I feel dizzy when I change position (lie to sit or stand).
10. I feel dizzy when I turn my head.

- Yes
- No
- Not sure

The Dizziness Symptom Inventory

The following list of symptoms may be experienced during or after a dizziness attack. Please check all that apply:

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10. I feel dizzy when I turn my head.

- Yes
- No
- Not sure

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7. I feel dizzy when I stand up or sit down.
8. I feel dizzy when I move suddenly.
9. I feel dizzy when I change position (lie to sit or stand).
10. I feel dizzy when I turn my head.

- Yes
- No
- Not sure
Scoring system for the DSP

- Subscales have 3-5 items each
- All subscale scores are normalized to yield 100 points maximum

How is the score calculated for a 3-item subscale?:
- 3 items in the subscale x maximum of 4 points per item (i.e. each response is 0 – 4) = 12 point maximum score 100/12 = 8.33. This means that each point is worth 8.33%.

How is the score calculated for a 5 item subscale?:
- 5 items in the subscale x maximum of 4 points per item = 20 point maximum score. 100/20 = 5. This means that each point is worth 5% (5 x 20 = 100%)

Patient DSP Summary Data Sheet
Set 60% as the threshold for affirmation/endorsement
Ear Specialist Summary Data Sheet

Data Sheet

Date: __________________________

MRN: __________________________

Please choose at least 1, or at most 3 diagnoses for your patient in rank order (#1 = highest likelihood, #3 = lowest likelihood) based on your history and physical examination.

1. Migraine associated vertigo (MAV)
2. Meniere’s Syndrome

3. Benign paroxysmal positional vertigo
4. Chronic subjective dizziness (anxiety-related dizziness)
5. Superior semicircular canal dehiscence
6. Vestibular neuretis
7. Other

Subject Characteristics

- N = 195
- Mean age: 59 years
- Range 17-86 years
- 74 male
- Administered DSP prior to the physician visit and then compared to physician’s differential diagnosis (i.e. rank-ordered list of potential diagnoses prior to testing etc)
Predicted = DSP  
Observed = Ear specialist  
Overall % Predicted Correctly = 70.2%

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<th>Men.d</th>
<th>SCD</th>
<th>VN</th>
<th>BPPV</th>
<th>3PD</th>
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Mig = vestibular migraine, Men. D = Meniere’s, SCD = superior SCC dehiscence, VN = vestibular neuritis, 3 PD = persistent, postural, perceptual dizziness, Unst = unspecified (utricular?) unsteadiness

Preliminary Findings N = 195

- Best classification accuracy thus far:
  - Meniere’s d.
  - Vestibular migraine
  - BPPV
  - Otolith end organ unsteadiness
- N’s too small for
  - SCD,
  - Neuritis/labyrinthitis,
  - PPPD
Application of DSP

Case Study

- 43 yo female patient with sudden onset severe vertigo 3 weeks ago lasting days to a week
- Initially hospitalized and treated with steroids and suppressants
- Reports they are improving slowly.
Audiogram

Self-report Measures

- **DHI**: 62/100 severe, self-report, dizziness handicap
- **HADS**
  - HADS anxiety subscale: 7/21 normal
  - HADS depression subscale: 3/21 normal
- **Dizziness Symptom Profile (DSP)**
Dizziness Symptom Profile (DSP)

Category Scores

- Vertigo
- Ocular Dizziness Symptom Profile (ODSP)
- Ocular Velocity Profile (OVP)
- Vestibular Neuropathy
- Superior Canal Dehiscence
- Migraine

vHIT

Reduced gains to the right with overt and covert saccades for rightward head impulses
Caloric Test
100% right unilateral weakness
no response to ice water

Rotary Chair Examination
cVEMP

oVEMP
Absent on the right
Impression

- Most likely a right, superior neuritis
- Partially compensated
  - Spontaneous nystagmus
  - Reduced VOR gain on vHIT and rotary chair
  - However, the patient is generating covert saccades
- Requires VRT
- Withdraw any suppressants
What comes next?

- Field-testing (we think we know how useful it will be but will not know until others gain experience using the DSP)
  - We will make available the DSP at no charge.
  - There will be a statement of indemnification that will say that, in the end, you are, or the physician is, responsible for any diagnostic or treatment decisions you make based on the results of the DSP
- Send requests to: gary.jacobson@vumc.org

End
Video head impulse test results and dynamic visual acuity: Relationships in unilateral vestibular impairment

Richard A. Roberts, Ph.D.
Vestibulo-ocular Reflex (VOR)

**Purpose:** maintain visual target on most sensitive part of retina (fovea) during head movement by moving eyes equal and opposite of the head movement

Vestibular  $\rightarrow$  Brainstem  $\rightarrow$  Eye Muscles

Inaccurate vestibular information leads to blurred vision as visual target slips from fovea

Dynamic Visual Acuity

Comparison of visual acuity with head still (no VOR) to visual acuity with head motion (VOR)

Measured using a value (logMAR)

**Normal vestibular function:** No difference in head still visual acuity vs. head movement visual acuity = lower logMAR difference

**Uncompensated vestibular dysfunction:** Visual acuity with head movement is poorer (VOR impairment) than visual acuity with head still

= higher logMAR difference
Common logMAR findings for three participant groups.

Normal performance is <0.58 (2 SD; Vital et al. 2010)

Video Head Impulse Test

- Uses high speed camera and accelerometer to capture eye movement responses elicited by head movements

- Eye movement velocity should equal head movement velocity to keep visual target maintained on fovea of retina

- Measure VOR Gain and Saccadic eye movements
Normal Vestibular Function

Eye Velocity should equal Head Velocity for a “VOR Gain” close to 1.0

Minimal or no saccadic eye movements since the eyes are keeping up with the head movement.

Figure used with permission of Wettstein, V.G. and Journal of Vestibular Research

Impaired Vestibular Function

Eye Velocity much less than Head Velocity – eyes are not keeping up with head movement which leads to very fast eye compensatory eye movements – saccades – attempting to move the eyes to the correct position

Saccades that occur after the head movement are termed “overt”
Saccades that occur during the head movement are termed “covert”

Figure used with permission of Wettstein, V.G. and Journal of Vestibular Research
V.G. Wettstein et al. / Compensatory saccades in head impulse testing

**Figure 7.** With intact VOR, eye velocity matches head velocity during head impulses, depicted on the right side. On the left, multiple covert saccades are seen after head impulse as compensatory head movements. Covertly, the patient has a pathologically low DVA value to the left (shown below the graph). Right side DVA is within normal range.

*Figure used with permission of Wettstein, V.G. and Journal of Vestibular Research*

**Figure 8.** Appearance of covert saccades during head impulses to the left in a patient with deficient VOR. Normal gaze values and no significant saccades to the right. Conversely, the patient has normal DVA values to both sides in spite of left side vestibular loss.

*Figure used with permission of Wettstein, V.G. and Journal of Vestibular Research*
Figure used with permission of Wettstein, V.G. and Journal of Vestibular Research.
Wettstein et al. (2016)

- Measured DVA and vHIT
  - DVA – SVA = Visual Acuity loss in logMAR
  - vHIT: VOR Gain, Overt Saccade Amplitude, Percent impulses with Covert Saccades
- Patient Group (n = 24)
  - Labyrinthectomy or Vestibular Neurectomy or otherwise determined to be permanent loss
  - Age (21 – 67; Mean = 48 years)
- Control Group (n = 113)
  - No history of Otologic or Neurologic issues
  - Age (19 – 83; Mean = 38 years)
- Is there a relationship between compensatory saccadic eye movements measured with vHIT and DVA performance?

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<tr>
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<th>VOR Gain</th>
<th>DVA logMAR</th>
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<tr>
<td>Impaired</td>
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UVL, healthy side performed similar to controls
UVL, impaired side had lower VOR Gain and poorer (higher) DVA
However, many UVL impaired actually had normal DVA
Presence of Covert Saccades and DVA

Controls: The majority of controls had covert saccades on less than 20% of impulses.

UVL: As percentage of impulses with covert saccades decreases, get poorer DVA performance (higher logMAR)

Overt Saccade Amplitude and DVA

Controls: Clustered with very few, low amplitude overt saccades
UVL, healthy side performed similar to controls
UVL, impaired side as overt saccade amplitude increases, have poorer DVA (higher logMAR)
For patients with reduced VOR gain due to unilateral peripheral vestibular impairment:

- DVA performance improves with presence of covert saccades
- DVA performance improves with decrease in overt saccade amplitude

Supports the role of these saccadic eye movements in compensation to vestibular impairment.

Why is this important?

- Understanding processes underlying compensation
- Identification of patients for VRT
- Tracking progress of therapy

Vestibular Weakness: Cognition and Driving

Dr. Kelsey Hatton
Bilateral vestibular weakness & cognition

- Both otolith organ and semicircular canal function contribute to:
  - spatial cognition
  - object recognition
  - numerosity
  - perception of body motion
  - theta rhythm maintenance
    (allows building “maps” and encoding spatial memory)

- Cognition allows:
  - self-motion perception, bodily self consciousness,
  - spatial navigation, spatial learning, spatial memory,
  - object recognition memory

(Hitier, Besnard & Smith 2014)

Bilateral vestibular weakness & cognition

- Vestibular dysfunction contributed to cognitive impairment above and beyond age-related changes on:
  - New pattern learning  Spatial Working Memory  Reaction Time
  - Pattern Recall  Sequence Memory  Visual processing speed

- Patients with vestibular loss have reduced hippocampal volume and impaired navigation and spatial memory functions

- Patients with vestibular dysfunction have an 8x odds ratio increase of difficulty on concentration or memory tasks.

- Short term memory difficulty/loss leads to poorer posture, which increases falls risk irrespective of state

(Smith et al 2018, Wei & Agarwal 2017)
BW & Driving

- Vestibular impairment affects spatial aspects of driving, such as:
  - staying in lane
  - low light driving conditions
  - changing lanes
  - reading accuracy/comprehension of signage
  - pulling in/out of parking spaces
  - slower checking blind spots

- Paper-and-pen visuospatial tests are predictive of on-road driving performance:
  - Intersecting pentagon drawing
  - Clock face drawing
  - Block design test

- 60% of patients Meniere’s disease or chronic vestibulopathy, and 30% of patients with acoustic neuroma resection report driving difficulty.

(Wei & Agarwal 2017, Wei et al 2017)

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BW & Driving

- 3071 subjects 50 years and older who completed a national survey (National Health and Nutrition Examination Survey NHANES) and in-person physical were tested.
- Estimation of vestibular dysfunction was completed via non-specific postural assessment (eyes open firm surface, eyes closed firm surface, eyes open foam surface, eyes closed foam surface).
- Failure of condition 4 (eyes closed foam surface) was the group of interest, 1594 participants fell into this group.
- Questionnaire to gauge dizziness, reports of falls, and driving difficulty:
  - “during the past 12 months have you had dizziness or difficulty with balance?”
  - “during the past 12 months have you had difficulty with falling?”
  - “How much difficulty do you have driving during daytime in familiar places?”

(Wei & Agarwal 2017, Wei et al 2017)
BW & Driving

- Driving difficulty increased significantly with increased age, poorer visual acuity, positive report of falls, and vestibular dysfunction groups
  - Vestibular dysfunction via questionnaire associated with 1.47x increased odds of driving difficulty
  - Vestibular dysfunction on questionnaire and during in-person physical on condition four had 4.3x increased odd of driving difficulty
  - Every additional second of holding condition 4 decreased odds of driving difficulty
  - Report of driving difficulty via questionnaire associated with 5.38x higher odds of falling
  - Vestibular dysfunction in clinic and report of driving difficulty associated with a 13.01x increased odds of falling compared to those denying driving difficulty
- 44% of adults reporting bilateral vestibular weakness via survey reported stopping driving or changing driving habits

(Wei & Agarwal 2017, Wei et al 2017)

References

- Vestibular Weakness, Cognition, and Driving: