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Vanderbilt Audiology Journal Club: What's New in the Clinical Vestibular Sciences?

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

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Chiarovano E, Vidal P-P, Magnani C, Lamas G, Curthoys IS, deWaele C. 2016. Absence of rotation perception during warm water caloric irrigation in some seniors with postural instability. Frontiers in Neurology 7(4) 1-8.

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Vanderbilt University Medical Center

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Introduction

- **Standing in darkness or on foam with eyes closed for 30 sec is an impossible task for 2/3 of individuals over the age of 70 years.**
- **Canal function may not decrement with age,**
- **Otolith end organ function is reduced with age**
- Research suggests that **age-related CNS changes have an effect on vestibular perception**
  - No effect of age on perception of self-motion perception
  - **There is an increase in the variability of vestibular perception threshold**
- **Age decreases activation of ipsilateral parieto-insular vestibular cortex (PIVC) following caloric stimulation**

Purpose

- **The effect of age on perception of motion during caloric stimulation has not been studied.**
- The **relationship between the absence of perception of caloric-induced vertigo and falls has not been studied.**
- **Investigators proposed to study 2 groups of subjects**
  - **Subjects with postural instability with absence of vestibular perception during caloric testing, and**
  - **Age-matched normal controls**
- Hypothesized that **falls in elderly may result from "vestibular neglect" due to an inappropriate central processing of normal peripheral inputs**

Methods

- **N = 10 seniors, patients (6 female, mean age 77 years, +/- 8 years)**
  - **Complained of postural instability** ("I feel like I'm walking like a drunk but I have not consumed alcohol").
  - Wall-walkers
  - **Felt like they were on a rocking boat**
  - **Maximum bithermal asymmetry 25%**
  - **<u>No vertigo perception post caloric irrigation despite a nytagmus SPV of > 15 deg/sec</u>**
- **N = 10 seniors, age and sex-matched controls (74 years, +/- 6 years)**
  - **Both left and right caloric mean max SPV had to exceed 15 deg/sec**
  - No comment re maximum allowable monothermal asymmetry
  - **Maximum bithermal asymmetry = 25%**
- **Exclusionary criteria included: if they experienced vertigo, history of end organ disease, neurological impairment or abnormal MRI**

Measures

- **Dizziness Handicap Inventory** (DHI)- **Dependent variable**
- Caloric test (open loop water)
- **Video Head Impulse Test (vHIT) –Dependent variable**
- **Cervical VEMP** (cVEMP)- **Dependent variable**
- **Ocular VEMP** (oVEMP) – **Dependent variable**
- **Equitest (SOT) – Dependent variable**
- Vibration-induced nystagmus test
- Head-shaking nystagmus test
- Audiometric testing

Results - DHI

- **Patient group – mean total score 39/100 pts** (+/- 11)
- **Control group – mean total score 14/100 pts** (+/- 19)
- The group differences were statistically significant
  - P = 0.002

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Results – Caloric Test

- **No significant group differences in caloric mean peak SPV for warm or cool water**
- **Control subjects perceived rotation when the maximum SPVs ≥15 deg/sec.**
  - Direction of perceived rotation was toward the side of the fast phase
  - Perception of rotation was absent when SPV was ≤ 10 deg/sec
- **Patients – failed to perceive rotation i.e. "absolutely no sensation at all of head or body rotation" when max SPV exceeded 15 deg/sec**

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Results: Horizontal canal vHIT

- **No significant group difference in mean HVOR gain** measured either by slope or area methods.

Results - cVEMP

- **No significant group differences for P13 and N23 latencies or normalized amplitudes.**
- **Absent cVEMPs** from:
  - **Patient group – 40%**
  - **Control group – 30%**

Results - oVEMP

- **Air conducted tone burst stimulus**
  - **Mean peak to peak n1-p1 amplitude significantly lower for the patient group**
  - No significant group differences in latency
  - 60% of patients and 30% of controls failed to generate a response
- **Bone conducted vibration at Fz**
  - **Mean peak to peak n1-p1 amplitude significantly lower for the patient group**
  - No significant group latency differences
  - 60% of patients and 20% of controls failed to generate a response
- **Bone conducted vibration at mastoid**
  - **Mean peak to peak n1-p1 amplitude no significant group difference**
  - No significant group latency differences
  - 20% of patients and 10% of controls failed to generate a response

Result - Equitest

- **Control group – Normal SOT**
- **Patient group – Could not maintain balance on condition 5 (eyes closed, sway referenced platform) and condition 6 (eyes open, sway referenced platform and vision).**
  - 80% fell on conditions 5 and 6
  - 20% had a low score on condition 5 and fell on condition 6
- **Subjects without perception of vertigo during the caloric test could not maintain balance in condition 5.**
- We are primarily dependent on vestibular inputs to maintain balance during ambulation.

Summary of Results

- Patients:
  - Were unsteady (subject selection criterion) and…
  - Were able to generate mean peak caloric induced nystagmus SPV of $\geq$ 15 deg/sec, and…
  - Did not sense movement following the caloric irrigation, and…
  - Generated significantly smaller oVEMPs compared to controls for acoustic stimuli.

Discussion

- The patient group experienced a lack of perception of self-rotation despite having a normal caloric response.
- These subjects demonstrated an inadequate postural strategy to maintain balance in SOT Conditions 5 and 6. Therefore the absence of movement perception during caloric testing, in an unsteady patient, may be a marker for a falls risk which has not been considered before.
- These results are consistent with Diard et al – described patients with normal caloric tests but with impaired balance on Conditions 5 and 6 as **"vestibular omission"**
- Current paper is first report of dissociation between horizontal canal function and perception of rotation during caloric stimulation in elderly subjects. The authors suggest that this phenomenon be referred to as "vestibular neglect."

Discussion

- In the Discussion section the investigators hypothesize that a deficit of central processing of vestibular information exists in patients exhibiting "vestibular neglect."
- The investigators suggest that the lack of self-motion perception during the caloric test, coupled with a complaint of postural stability should draw the clinicians attention to the possibility of postural instability and the need to implement measures to prevent falls

Discussion – Explanations of how it is possible to have normal hVOR, and no perception of post-caloric vertigo in a patient with postural instability

- Differences between vestibulo-ocular, vestibulo-subcortical and vestibulo-cortical pathways
- VOR is a trisynaptic pathway linking canal sensors to extraocular motorneurons.
- Pathway underlying perception of self-motion is polysynaptic and distributed: vestibular nucleus, thalamus (PIVC, temporal superior gyrus, inferior parietal lobe and insula (where multisensory inputs converge)
- Complex circuitry could be more sensitive to the aging process than a 3 neuron arc of the VOR.

Shortcomings of this study

- Authors selected patients with no perception of post caloric vertigo and who had a history of postural stability. Any surprise why there were significant group differences?
- There was no attempt to measure the integrity of the somatosenses as a contributor to the patient's postural instability.
- There were significant between group differences in the functional integrity of the utriculo-ocular reflex. Subjects with absent oVEMPs in response to air conducted tonebursts complain primarily of postural instability as did the patients in the current report.
- vHIT data was specific only to the hSCC. The investigators did not collect data pertaining to the integrity of the vertical canals

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Conclusion

- Authors asserted that the dissociation between motion perception and objective vestibular responses may be a determinant of postural instability (PI) because it is these same seniors who demonstrate greater PI than age-matched controls.
- Failure to perceive rotation during caloric testing when the SPV is $\geq$15 deg/sec in an unsteady patient should encourage the clinician to assess the patient's falls risk and intervene
- Future studies = Evaluate the proportion of PI seniors without vestibular perception amongst a larger population of patients with complaints of dizziness and PI

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Age predicts the absence of caloric-induced vertigo. Jacobson, Piker, Grantham and English. J Otology, In press, 2018.

Age predicts the absence of caloric-induced vertigo. Jacobson, Piker, Grantham and English. J Otology, In press, 2018.

- The previous investigation implied that lack of vestibular perception was a vestibular disorder of aging.
- We wanted to test that hypothesis.
- N = 92 consecutive patients (age, sex characteristics in slide)
- All subjects had either monothermal or bithermal open loop water caloric test (began with monothermal warm).
- All subjects were asked after the two caloric irrigations:
- *"Other than the temperature of the water, did you have any other perceptions after the water stopped flowing in your ear?"*

Jacobson, Piker, Grantham and English, 2018, In Press.

- Both age and SPV were significant predictors of vertigo perception during the caloric exam:
- **increased age was associated with increased SPV and decreased perception of motion**
- Association between age and caloric perception is not definitive as ~ ½ of the patients reporting an absence of vertigo were under the age of 65 years.
- Additional research is justified since there is evidence that lack of vertigo exists in older patients with BPPV compared to younger patients
- There is evidence suggesting that vertigo perception is a central processing issue.

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Demographics of the two groups (Presence of vertigo, Absence of Vertigo) including their gender distribution, mean age, and mean SPV.

Predictor Variables	Group		Total Cohort (n=92)
	Presence of vertigo (n=69)	Absence of Vertigo (n=23)	
Gender	38 females 31 males	13 females 10 males	51 females 41 male
Age (SD)	56.51 (18.0)	66.55 (16.9)	59.18 (18.2)
SPV (SD)	34.25 (14.9)	26.22 (7.9)	32.24 (13.9)

SPV = slow phase velocity, given in deg/sec

SD = standard deviation

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End

Skull Vibration-induced Nystagmus Test (SVINT)

"The Vestibular Weber"

Richard A. Roberts, Ph.D.

European Annals of Otorhinolaryngology, Head and Neck diseases 133 (2016) 343–348

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com/en

Technical note

How to perform the skull vibration-induced nystagmus test (SVINT)☆

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Weber test

ABSTRACT

The skull vibration-induced nystagmus test is a robust, nonintrusive and easy to perform test. This test acts as a vestibular Weber test and is performed as a bedside examination. It usually instantaneously reveals vibration-induced nystagmus (VIN) even in long standing or chronic compensated unilateral vestibular lesions. The test requires stimulation at 30, 60 or more efficiently at 100 Hz. The vibrator is applied perpendicularly to the skin on a subject sitting up straight on the right and then the left mastoid (level with external acoustic meatus) and vertex. The VIN can be observed under videonystagmoscopy or Frenzel goggles. Either the direct tracing or the VIN slow phase velocity can be recorded on a 2D or 3D videonystagmograph. The patients should be relaxed and not treated by strong sedative medications. This rapid first-line test is not influenced by vestibular compensation and usefully complements other tests in the multifrequency evaluation of the vestibule. It acts as a global vestibular test by stimulating both canal and otolithic structures at 100 Hz. It is useful in case of external acoustic meatus or middle ear disease as a substitute for the water caloric test and is preferable in elderly patients with vascular disease or arthritis of the neck to the head-shaking-test or head-impulse-test.

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Skull Vibration-Induced Nystagmus Test (SVINT): "Vestibular Weber"

Basis: vibration applied to skull induces sufficient labyrinthine fluid displacement to activate Type I hair cells in semicircular canals and otolith organs to create measurable, phase-locked afferent firing

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SVINT Technique

- Vibration applied to vertex and each mastoid area
  - Mastoid best for most vestibulopathy
  - Vertex better for Superior Canal Dehiscence
- Patient is vision-denied
- 100 Hz vibration is ideal to stimulate all vestibular structures

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What SVINT Tells Us

- Presence of nystagmus indicates asymmetry
  - SVINT is not very sensitive to CNS issues (10-30%)
  - Most likely related to peripheral vestibular issue

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What SVINT Does <u>Not</u> Tell Us

- Compensated vs. uncompensated
  - Even patients with well-compensated vestibular impairment can have vibration-induced nystagmus
- Type of pathology
- Involved ear

SVINT Interpretation

Normal System
- No nystagmus because no asymmetry at vestibular nuclei
- Specificity is 94%

Symmetrically Impaired
- No nystagmus because no asymmetry at vestibular nuclei

SVINT Interpretation

Abnormal
- Nystagmus beats to healthy side **91%** of time
  - Total UVD: 98% Sensitivity
  - Partial UVD: 75% Sensitivity
    - increases as caloric asymmetry exceeds 50%
- Nystagmus beats to lesion side **9%** of time
  - Third window issues (i.e. Superior Canal Dehiscence)
    - 82% Sensitivity
    - 30% have up-beating
  - Some patients with Meniere's disease (20%)

Dumas Recommended Vibration Devices

ABC (Germany)
ISV 1:EP500 (Amplifon, France)
VVSED 500 (Euroclinic, Italy)
NC70209 (North Coast Medical, USA)
VVIB 3F (Synapsys, Marseille, France)

Contraindications

- Dumas reports using this type of vibration in at least 18,500 with no side effects
- Caution may be considered in cases of:
  - Recent middle ear surgery
  - Detached retina
  - Subdural hematoma
  - Poorly controlled anti-coagulant therapy

Summary

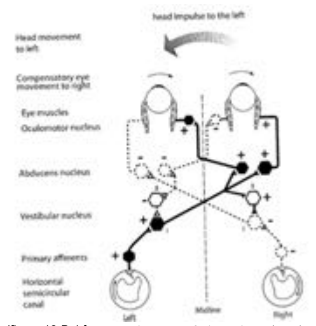
SVINT is a low-cost screening test with excellent sensitivity/specificity for peripheral vestibular asymmetry. Nystagmus will beat to the healthy ear in most cases except SCD and some cases with Meniere's disease.

"A new saccadic indicator of peripheral vestibular function based on the video head impulse test"

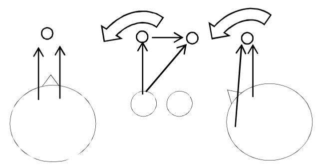
(i.e. SHIMP)

2016, MacDougall HG, McGarvie LA, Halmagyi GM, Rogers SJ, Manzari L, Burgess AM, Curthoys IS, Weber KP

Saccadic health



(figure 16-B-1 from: Jacobson, G.P., & Shepard, N.T. (2014). Balance Function Assessment and Management – 2nd Edition. © 2014 Plural Publishing – Used by permission.)



- Eye movement integral for VOR
- ~200ms latency after appearance of target of interest
- Actual movement to acquire target is ~50-100ms long
- Velocity up to 30,000 degrees/sec [2]
- Controlled by occipitoparietal cortex, frontal lobes, basal ganglia, superior colliculus, cerebellum, and brainstem (midbrain to pons)
- Saccades generally unaffected by age, calibrated by cerebellum

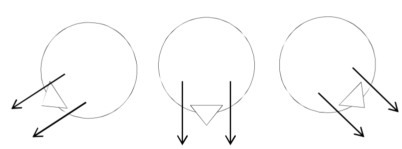
(Jacobson & Shepard, 2014)

Oculocephalic/Doll's Eye Reflex

- Eyes follow examiner: intact brainstem
  - Positive Doll's eye test

– Eyes fixed midorbit: nonfunctioning brainstem
  - Negative Doll's eye test

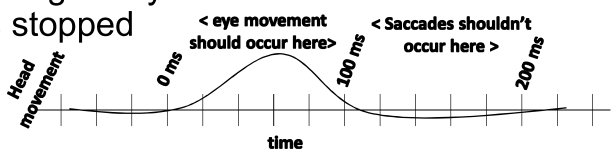
Image: By Thomas Quine (Dolls with crazy eyes) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons



(Nathanson et al 1957)

Head Thrust Testing (HTT)

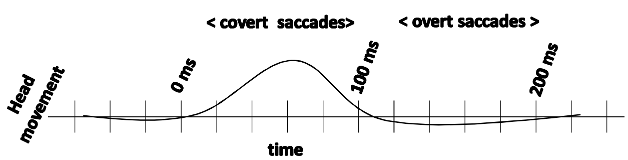
- Patient fixates on visual target while head is turned 15-20 degrees to one side
- Guide patient's head through a quick head turn (>200 deg/sec²) while they attempt to maintain visual target
- Patient must maintain passive neck muscles and allow examiner to move/control head
- Looking for eye movements after head movement has stopped



(Schubert et al 2004)

Head Impulse Paradigm (HIT/HIMP)

- First described by Halmagyi and Curthoys (1988)
  - Saccadic eye movement with head turns of patients with unilateral vestibular neurectomy or bilateral peripheral vestibular system impairment
  - Initially performed with a scleral coil
  - Now performed with the video systems



(Macdougall et al 2009, 2013, Weber et al, 2009)

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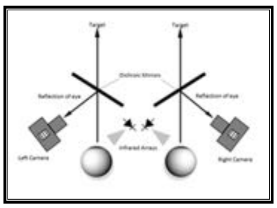
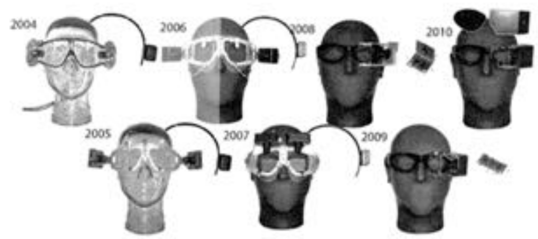
Head Impulse Paradigm (HIT/HIMP)

- Video-oculography
  - Accuracy of cameras tracking pupils has been validated against use of scleral coil
  - FDA approval 2013





(figure 5-2 from: McCaslin, D.L. (2012). Electronystagmography/ Videonystagmography. © 2012 Plural Publishing
& figure 16-C-1 from: Jacobson, G.P., & Shepard, N.T. (2014). Balance Function Assessment and Management – 2nd Edition. © 2014 Plural Publishing – Used by permission.)

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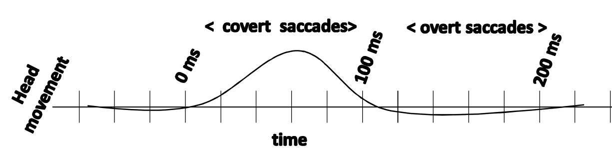
Head Impulse Paradigm (HIT/HIMP)

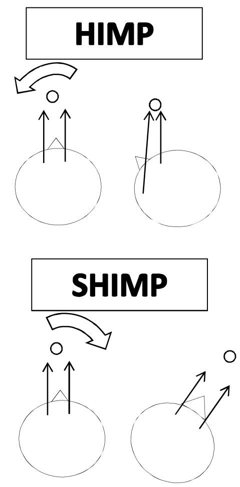
- Able to observe compensatory saccades or "catch up" saccade patterns
- Patient head is moved, visual target is static
- Normal subjects do not need compensatory saccades
- Abnormal saccade patterns on this test indicate vestibular impairment, requiring catch up saccades be generated to regain the fixed target



(Perez & Rama-Lopez 2003, MacDougall et al 2013)

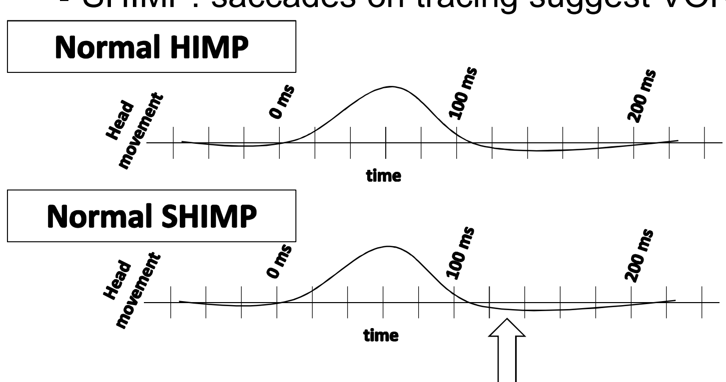
Suppression Head Impulse Paradigm (SHIMP)

- Described by MacDougall et al (2016)
  - Instead of target being "earth-fixed", target is "head-fixed"
  - Normal subjects create large saccade after the head stops moving
  - Weak or absent saccades were noted for patients with unilateral vestibular or bilateral peripheral vestibular system impairment



SHIMP and HIMP

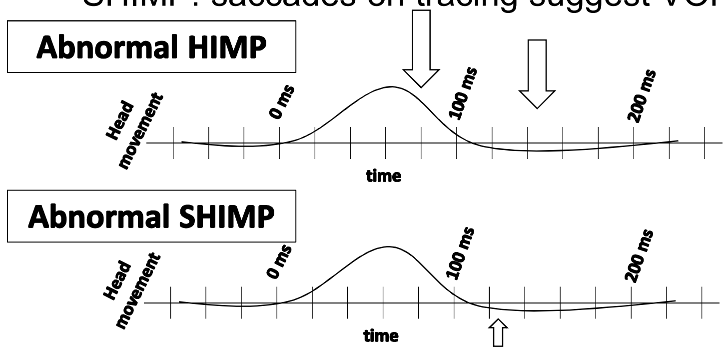
- Proposed as complementary tests
  - HIMP: saccades on tracing suggest VOR dysfunction
  - SHIMP: saccades on tracing suggest VOR function



(MacDougall et al 2016, McGarvie et al 2015)

SHIMP and HIMP

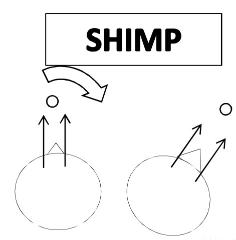
- Proposed as complementary tests
  - HIMP: saccades on tracing suggest VOR dysfunction
  - SHIMP: saccades on tracing suggest VOR function



(MacDougall et al 2016)

Suppression Head Impulse Paradigm (SHIMP)

- Benefits of SHIMP:
  - Anti-compensatory saccades suggest VOR function
  - Anti-compensatory saccades may be present for patients with vestibular weakness, even when compensatory saccades are not. This helps determine whether or not a bilateral weakness is considered total
  - Anti-compensatory saccades occur later, about 185ms into tracing. This makes them more easily observable and being in one area is likely easier to mathematically analyze/quantify.



(MacDougall et al 2016)

Suppression Head Impulse Paradigm (SHIMP)

- Evaluating whether patient is able to produce "anti-compensatory" saccades
- Patient head and target are moved simultaneously
- Normal subjects with healthy VOR will have to make a second saccade to adjust after the head stops moving to acquire the target
- Abnormal saccade patterns on this test are reduced or do not occur after head stops moving because the eyes rotated with the head movement (abnormal VOR response)

(MacDougall et al 2016)

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