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“The Current State of Video Head Impulse Testing”

Devin L. McCaslin, Ph.D.
Division of Audiology
Division of Vestibular Sciences
Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences
Vanderbilt University Medical Center

Disclaimers

• I have consulted with
  – Oticon Medical
  – Interacoustics
  – Intelligent Hearing Systems
Learning Outcomes

• After this course, participants will be able to:
  – 1) Describe the measurement parameters of the vHIT.
  – 2) Describe the clinical utility of the vHIT in assessing peripheral unilateral impairments
  – 3) Describe how the vHIT can detect central impairments.

Introduction

• We cannot use imaging or any other sort of anatomical evidence to confirm an impairment in the vestibular system
• The clinicians interpretation of findings from tests of peripheral vestibular function are critical to achieving a correct diagnosis.
Introduction

• The clinical assessment of the peripheral vestibular system often consists of comparing the level of function from similar end-organs.
• In order to correctly interpret tests of vestibular function, the clinician must thoroughly understand the anatomical and physiological underpinnings of the tests.
Patterns

Semi-Circular Canals
Ewald’s Laws

MacDougall et al., *Otology & Neurotology*, 2013

VOR: Frequency and Gain
Gain is best above .1 Hz and poorest below

[Graph showing gain and frequency relationship with different movement types like Caloric, Active Head Movement, and Rotational Testing]
Responses from the Semicircular Canal Afferents

The dynamic range is different for excitatory and inhibitory responses (Ewald 1892).

Goldberg and Fernandez, 1971

Background of the Head Impulse Test

- Halmagyi and Curthoys (1988)
- Doll’s eye test
Then….                                       Now…

HIT Technique

• Patients are asked to maintain gaze on an earth-fixed target (1 meter away)
• The head is grasped by the examiner and moved in a high acceleration low amplitude movement (10-20 degrees-horiz).
• A patient with intact vestibular function will be able to maintain their gaze on the target.
• A patient with an impairment will generate one of two types of saccades.
Vestibulo-ocular Reflex (VOR)

“Catch-up saccade”
Normal HIT

Abnormal HIT

Technique

- Must be an abrupt impulse/acceleration (i.e. > 50 degrees per second) since the oculomotor system can compensate for head movement at low frequencies).
- When a head velocity exceeds approximately 100 degrees per second the VOR is the sole contributor to the corresponding eye movement.
Technique is Critical

• Low noise of the coil method allows for high spatial (< 1 degree) and temporal (less than 1 msec) resolution.
Comparison of Techniques

Bartl et al., *Annals of the New York Academy of Sciences*, 2009

Video-oculography

[Diagram showing different techniques and their comparisons]
What is Measured?

- Position of the eye
- Head velocity in 3-dimensional space

RALP and LARP

- Spatial Arrangements:
  - The three SCC are at right angles to each other so that they lie in the three planes of space (corner).
Vertical HIT
Calibration for Vertical Channels

Right Anterior - Left Posterior
Left Anterior – Right Posterior

MacDougall et al. 2009
“The video head impulse test”

Normal head velocity  Normal eye velocity

Eyes move perfectly out-of-phase with the head with few, if any, catch-up saccades
Eye and Head Velocity

MacDougall et al. 2009
“The video head impulse test”

Patient with left-sided impairment of, at least, the hSCC (or superior vestibular nerve)
Eye and Head Position

Saccade Classification

Weber et al., Neurology, 2008
Calculation of VOR Gain

Factors Considered for Interpretation

- Vestibulo-ocular Reflex Gain
  - Speed or position of the eye vs. head
- Catch-up saccades (direction, velocity, timing)
  - Overt
  - Covert
- Gain Asymmetry
  - Impulses to the left vs. right
Factors Considered for Interpretation

Abnormal vHIT

Covert Saccade

Overt Saccade
Unilateral Vestibular Lesion

Abnormal vHIT
EyeSeeSix Final Report
vHIT and Compensation

Initial head impulse test

Impulse test hours later

Blodow et al., Ausis Nasus Larynx, 2013

Variations of Responses

Blodow et al., Ausis Nasus Larynx, 2013
We now have tools to assess low frequency (caloric) and high frequency function in the vestibular system.

HIT testing and caloric testing can be different thus each provides unique information.

Good for bedside testing (e.g. inpatients)

Well-tolerated

Is relatively quick to do.
vHIT and Peripheral Vestibular Impairments

Chen et al., Neurology, 2014

• Ipsilesional gains were low.
• Contralesional gains were reduced by approximately 20%.
Gain and Impairment

Recent Vanderbilt Study

Unilateral Peripheral Vestibular Impairments!
Objectives

• To determine if a predictable relationship existed between self-reported dizziness handicap and vHIT.
• Describe the characteristics of vHIT ipsilesional and contralesional vestibulo-ocular reflex slow phase velocity in patients with varying levels of canal paresis.

Objectives (con’t)

• Determine the sensitivity and specificity of the vHIT for detecting horizontal semicircular canal impairment using the caloric test as the "gold standard."
Design

- Subjects were 115 adults 65 years were included in the study (mean age 45.63 years [sd = 14.91], 58 males) presenting to a tertiary medical care center with symptoms of dizziness.
- Participants were administered a measure of self-report dizziness handicap (i.e. Dizziness Handicap Inventory DHI) and underwent caloric testing and vHIT at the same appointment.

Design

- Extensive data cleaning was imposed to eliminate artifacts.
  - Blinks and miniblinks
  - Excessive oscillations (tracking system loses the pupil)
  - Delay responses or phase shifts
  - Multi-peak responses (examiner contacts goggles)
  - Head bounce
  - Responses that go in the wrong direction
Design

- Caloric UW categories:
  - 0-26%
  - 26%-50%
  - 51%-75%
  - 76%-100%

- VOR responses from impulses with a velocity of less than 150 deg/sec were discarded.

Mean DHI Total Score and vHIT Outcome

![Graph showing mean DHI Total Score and vHIT Outcome](image)
Ipsilesional VOR Gain and CA

\[
F = 50.51, \text{ df } = 3, \ p \leq 0.000
\]

Contralesional VOR Gain and CA

\[
F = 4.097, \text{ df } = 3, \ p \leq 0.008
\]
Results - Peripheral Impairments

• A cut-off point of 39.50 percent caloric asymmetry optimized best sensitivity and specificity.

• Using a >39.5% caloric asymmetry as the normal upper limit the positive predictive value of the vHIT was 0.93 and the negative predictive value 0.85.
Conclusions

- The level of self-reported dizziness handicap is not predicted by the outcome of the vHIT.
- vHIT and caloric data are not redundant
- Each test provides unique information regarding the functional integrity of the horizontal semicircular canal at different points on the frequency spectrum.

Conclusions

- However, our data shows that a caloric asymmetry of 39.5% is required to optimize discrimination between an abnormal and normal vHIT in cases of unilateral peripheral impairment.
- It is our contention that the vHIT is a complementary test to the balance function examination and should viewed as such rather than as a replacement for caloric testing.
Can Abnormal vHITs be Recorded in Patients with Central Impairments

YES!

Posterior Fossa

Edlow et al., Lancet Neurol, 2008
**Posterior Circulation Stroke**

Edlow et al., *Lancet Neurol*, 2008

**Abnormal vHIT Due to Posterior Circulation Strokes**

Edlow et al., *Lancet Neurol*, 2008

Chen et al., *Neurology*, 2014
Fact

• We still much we do not know all the patterns and ways in which the vHIT changes in different disorders and disease processes.
  – Cerebellar
  – Vestibular Nuclei
  – Peripheral
  – Disorders
    • Migraine
    • Meniere's
    • Vestibular neuritis
Challenges

• Blinks
• “Helping patient”
• Occasionally a test is not possible
• Training

Patient Non-compliance
What is the HINTS exam

• Three step clinical decision rule:
  – Composed of three eye movement exams that have been suggested to be critical in differentiating peripheral from central impairments of acute continuous vertigo/dizziness (not transient-BPPV).
    • Head impulse
    • Nystagmus type
    • Test of skew
HINTS

- HINTS:
  - Head Impulse
  - Nystagmus
  - Test of Skew
  - Hearing.
- 99% sensitivity
- 97% specificity for central vestibular disorders

Newman-Toker et al., Acad Emerg Med., 2013

The HINTS Exam

- Is the HINTS exam (Head-Impulse—Nystagmus—Test-of-Skew)
- A negative HINTS examination has been suggested to be able to rule out a stroke better than a negative MRI with DWI in the first 24 to 48 hours after symptom onset with a specificity of 96%.

Newman-Toker et al., Acad Emerg Med., 2013
Pediatric

Meniere’s Disease

vHIT and caloric results in Ménière’s disease 1

Title: The dissociation of video head impulse (vHIT) and bithermal caloric test results provide topological localization of vestibular system impairment in patients with “definite” Ménière’s disease.

McCaslin et al., 2014, American Journal of Audiology
The dissociation of video head impulse (vHIT) and bithermal caloric test results provide topological localization of vestibular system impairment in patients with definite Ménière's disease.

McCaslin et al., 2014 in press.

Audiometry
Abnormal Caloric Response

vHIT
vHIT in Meniere’s Syndrome

Figure 13H-11. Morphology of mammalian vestibular afferents as revealed by horseradish peroxidase-labeled axons in the inferior olive. A. Calyx from revealing a single type I hair cell. B. Calyx from revealing two Type I hair cells. Although the II. Dendritic spines inter- cell hyperpolarizes Type I hair cells. C. Calyx from showing a complex of two afferents, one of which is an inhibitory Type I afferent. Group I afferents project to the centrally arranged central, intermediate, and peripheral zones of the area. Shown are the two types of calyx, dendritic, and bouton fibres with each symbol representing a single hair-fibre. Dendritic arbors make up 10% of the population, bouton units 20%, and calyx units 10%. From Fernandez, Sato, and Goldberg.

continued
Current vHIT Studies

- Auditory Neuropathy
- Enlarged Vestibular Aqueduct
- Meniere’s vs. Migraine
- Monitoring pediatric Hem/onc patients

Questions