The Video Head Impulse Test: Administering and Interpreting the Test

Kamran Barin, Ph.D.
Assistant Professor, Emeritus
Department of Otolaryngology
The Ohio State University
barin.1@osu.edu
Disclosure: Consultant to Interacoustics and Bertec Corp.

18th Workshop on Neurotology and Medical Audiology
Kolkata, India
Nov 29-Dec 1, 2019
Overview

• Video head impulse test (vHIT) has become an important part of evaluation for patients with dizziness and other balance disorders
• The test is simple to perform and provides valuable information about all six semicircular canals
• Two main parameters, VOR gain and catch-up saccades, are used for interpretation of the test results but many questions remain:
  – What is the clinical significance of VOR gain?
  – What is the clinical significance of overt and covert catch-up saccades?
  – How to avoid artifacts and identify them when they occur
Bedside HIT – Normal Responses

- HIT consists of moving the head using small-amplitude high-velocity high-acceleration unexpected head movements as the patient fixates on a stationary target straight ahead
  - In order to avoid contamination from the oculomotor pathways, head velocities should be above 100°/sec for lateral impulses and above 50°/sec for vertical impulses
- In normal subjects, VOR eye velocities match the head impulse velocities in the opposite direction allowing the eyes to remain on the target after an impulse
vHIT – Normal Responses

- Head impulses toward the canal cause excitation from that canal
  - Changes in the neural firing are proportional to the head velocity
- Head impulses away from the canal cause inhibition from that canal
  - Neural firing is clipped (saturates) at 0 spikes/sec and does not provide an accurate measure of head velocity
- Both labyrinths contribute to generating eye movements
  - The contribution of the ipsilateral labyrinth is larger (Ewald’s second and third laws)
vHIT – Normal Responses

- In normal subjects, the VOR gain is around 1 at lower head velocities but begin to decline slightly at higher head velocities.
- At higher head velocities (~300°/sec) even normal subjects may have catch-up saccades
  - Stay below 250°/sec for lateral head impulses and below 200°/sec for vertical head impulses.
In patients with vestibular lesions, the eyes fall short of the target for head impulses toward the damaged side.

After the head comes to a stop, a catch-up saccade is generated to reach the target.

These saccades are called overt saccades because they are visible to the naked eye.
vHIT – Responses in Unilateral Vestibular Lesions

• For head impulses toward the side of lesion, the neural response from the damaged side is reduced or abolished.

• The neural response from the intact side is saturated and no longer proportional to head velocity.

• The resulting eye velocity does not match head velocity and the eyes fall short of target.

• \( \text{VOR Gain} = \frac{\text{Eye Move.}}{\text{Head Move.}} \ll 1 \) (decreases rapidly with increasing head velocity).
vHIT – *Responses in Unilateral Vestibular Lesions*

- For head impulses away from the side of lesion, the neural response from the intact side is proportional to head velocity.
- The neural response from the damaged side is again reduced or abolished.
- The resulting eye velocity is closer but still does not match head velocity and the eyes fall somewhat short of target.
- VOR Gain = Eye Move./Head Move. < 1 (decreases with increasing head velocity but not as rapidly as the VOR gain for head impulses toward the side of lesion).
vHIT – *Catch-Up Saccades*

- The mechanism for triggering catch-up saccades is intuitively understood to be the difference between the gaze and target positions at the end of a head impulse.
- After the position difference is detected and the saccade is initiated, it takes about 80-100 ms for the eyes to begin to move.
- These saccades have long latencies (>~250 ms)
  - They are called **overt** saccades because they occur after the head movement and are visible to the naked eye.
Bedside HIT – *Responses in Unilateral Lesions*

- Some patients are able to initiate saccades during head movements
  - The saccades are called *covert* saccades because they often (but not always!) occur during head movements and are not visible to the naked eye during the bedside HIT
- These saccades have short latencies (<~200 ms)
vHIT – *Covert Saccades*

- Coverts saccades require some form of learning and prediction
- Coverts saccades usually are followed by a small overt saccade
- In preliminary reports, covert saccades have been associated with compensation
  - Better dynamic visual acuity, improved balance, and reduced symptoms
vHIT Summary – *Unilateral Lesions*

- VOR gain is $<< 1$ for head impulses toward the side of lesion and declines with increasing head velocity.
- VOR gain is $< 1$ for head impulses away from the side of lesion but does not decline as much with declining head velocity.
- Significant catch-up saccades are present for impulses toward the side of lesion.
- Catch-up saccades can be present for impulses away from the side of lesion also but they are not as large and start at higher head velocities.
- Initially, most of the catch-up saccades are the long-latency type (overt).
- Over time, with learning and prediction, short-latency (covert) saccades may develop.
vHIT Summary – Unilateral Lesions

- In acute lesions, fast phases of spontaneous nystagmus will be intermixed with catch-up saccades for impulses toward the side of lesion and in the opposite direction of typical catch-up saccades for impulses away from the side of lesion.
- Spikes for spontaneous nystagmus can occur before or after head impulses.
Interpretation of vHIT
Different Patterns of Valid vHIT Results

A

B

C

D

Normal

UW Compensated

UW Acute

BW Partial
vHIT Interpretation – *Step-by-Step Guide*

- **Different types of eye movements in vHIT**
  - **Slow VOR eye movements**
    - VOR eye velocities are either shaped like the head velocities or in case of severe loss, they will appear as the clipped version of the head velocities
  - **Fast eye movements**
    - Long-latency catch-up saccades (overt)
    - Short-latency catch-up saccades (covert)
    - Fast phases of spontaneous nystagmus
  - **All others (artifacts)**
vHIT Interpretation – Step-by-Step Guide

• Step 1 – Identify the artifacts and determine if the test is interpretable
  – Delete impulses with artifacts as you need only a few impulses for interpretation
• When trying to identify saccade types, look at the individual impulse tracings
vHIT – Artifacts and Saccade Look-Alikes

• Two consecutive saccades going in opposite directions at about 80-100 ms apart
  – The patient is looking around
  – Reinstruct the patient

• Biphasic or uniphasic artifacts due to eye blinks, eyelids obstructing part of the pupil, or LED light intruding on the pupil
  – Shine a light to shrink the pupil
  – Pay attention to the display while performing the test
  – Delete affected impulses
  – Recording the video of eye movements can help with identifying these artifacts
vHIT – Artifacts and Saccade Look-Alikes

• High-frequency oscillations due to pupil detection issues
  – Adjust the cameras, the focus, and the threshold (in some systems)

Abnormally high or low VOR gain in the absence of catch-up saccades usually indicates an artifact (do a quick saccade test to rule out saccadic palsy)
vHIT – Other Artifacts
vHIT – Spontaneous Nystagmus

• Step 2 – Account for spontaneous nystagmus
  – Fast phases of spontaneous nystagmus appear as spikes in eye velocity tracings
  – Spontaneous nystagmus fast phases can occur before or after head impulses
  – For typical spontaneous nystagmus that beats away from the side of lesion, spikes appear in the opposite direction of VOR eye movements following head impulses toward the intact side
  – Fast phases of spontaneous nystagmus are intermixed with the catch-up saccades during head impulses to the lesion side

Modifying the display parameter can help with identifying nystagmus fast phases
vHIT Interpretation – Step-by-Step Guide

• Step 3 – Determine if abnormal catch-up saccades are present
  – Identify true catch-up saccades using the latency of first saccade
    • Short latency ~80-225 ms, long latency ~225-350 ms
  – Determine significant saccades using the saccade peak velocity
    • Use peak saccade velocity > 100°/sec or > half of the peak head velocity
    • Velocity may be too variable but there is no other established criteria

• When there are no significant catch-up saccades, check the VOR gains and if they are within normal limits (close to 1), vHIT should be considered within normal limits

• If VOR gains are not within normal limits in the absence of abnormal catch-up saccades, consider presence of an artifact
vHIT Interpretation – Normal Results

- No clearly-identifiable catch-up saccades
- VOR gains are close to 1 bilaterally
  - Head velocities are approximately equal for right-left impulses and within the optimal range
  - No other sign of artifacts
vHIT Interpretation – Normal Results

- There are few catch-up saccades bilaterally for higher head velocities
  - Saccade velocities are considerably smaller than the corresponding head velocities
vHIT Interpretation – *Step-by-Step Guide (continued)*

- **Step 4** – If abnormal catch-up saccades are present in one direction only and the VOR gain is abnormal for the same side, consider vHIT consistent with a unilateral lesion
  - If the VOR gain is normal in the presence of abnormal saccade, still consider the vHIT abnormal (may signify mild lesions)
  - The VOR gain to the opposite direction is usually normal but it does not contribute to the interpretation even if it is abnormal

- If abnormal catch-up saccades are present to both directions, there is no easy way to distinguish between purely unilateral and partial bilateral lesions
  - Assume unilateral unless proven otherwise
  - For unilateral lesions, catch-up saccades are more frequent to the side of lesion and start at lower head velocities
  - For unilateral lesions, VOR eye velocities are clipped/saturated for one direction but proportional to head velocities in the opposite direction
  - For bilateral lesions, the sum of right and left VOR gains is less than one
vHIT Interpretation – *Unilateral Vestibular Deficit*

- Abnormal catch-up saccades to both directions but more significant for rightward head impulses
  - Saturated VOR eye velocities for rightward head impulses and proportional VOR velocities for leftward head impulses denote a right unilateral vestibular deficit
    - VOR gain for leftward head impulses may be abnormal but interpretation is the same
vHIT Interpretation – *Bilateral Vestibular Deficit*

- Complete bilateral loss – Abnormal catch-up saccades and near 0 VOR gain for both directions
Summary

• Head velocities must be within a specific range and right-left velocity profiles must be approximately the same for valid interpretation of vHIT

• Catch-up saccades can be helpful in identifying abnormal vHIT
  – Abnormal catch-up saccades are more frequent and start occurring at lower head velocities
  – Presence of short-latency catch-up saccades has been associated with improved dynamic visual acuity, better balance, and reduced symptoms but more work is needed

• In the presence of abnormal catch-up saccades, vHIT should be considered abnormal regardless of whether the VOR gain is abnormal or not
  – Presence of consistent catch-up saccades with normal VOR gains is likely to represent a mild lesion

• Conversely, abnormal VOR gain in the absence of catch-up saccades should be investigated further for possible artifacts
Let’s Do a Test!

- Can we estimate the loss of canal function in this vHIT?
- Is the loss confined to the right canal?

R Gain = 0.42
L Gain = 0.87
Total R-L Gain = 1.29
Mean R-L Gain = 0.645
VOR Gain and the Level of Vestibular Loss

R Gain = 0.42
L Gain = 0.87
Total R-L Gain = 1.29
Total Loss% =
(2 – 2 \times \text{Total R-L VOR Gain}) \times 100 =
(2 – 1.29) \times 100 = 71%
DO NOT DO THIS!
(Different frequency ranges)

|UW%| = \frac{1 – \text{Mean VOR Gain}}{\text{Mean VOR Gain}} \%
= 55%
vHIT – *Clinical Applications*

- For the first time, isolated abnormalities in vertical canals and their afferent pathways can be identified
  - In vestibular nerve abnormalities, vHIT can determine which branches of vestibular nerve are involved and can determine when and if function returns to the vestibular nerve
- In the case of acute vertigo, can differentiate between cerebellar strokes and peripheral vestibular lesions (Newman-Toker et al, 2013)
- Can be used for serial testing (e.g., monitoring Gentamycin therapy for Meniere’s or monitoring vestibulotoxicity of different agents)
- Can be used in place of rotation testing in patients with bilateral caloric weakness
- Can be modified for testing children (e.g., before cochlear implant)
- Cost-effective because it reduces the need for unnecessary tests