Head Impulse Test – *Overview*

- First described by Halmagyi and Curthoys (1988) as a bedside test of the vestibulo-ocular reflex (VOR)
- Consists of monitoring eye movements as the patient fixates on a stationary target while the head is moved briskly to the right or left in the plane of lateral semicircular canals
- The test can be performed in the planes of right anterior-left posterior or left anterior-right posterior canal pairs but is technically more challenging

Head Impulse Test – *Bedside Test Procedure*

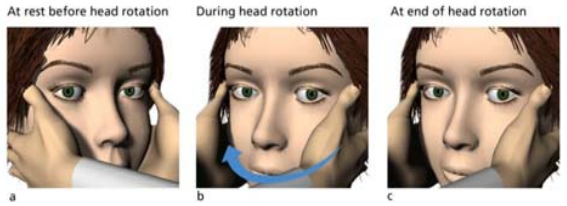
Right Lateral – Left Lateral

Right Anterior – Left Posterior

Right Posterior – Left Anterior

- Look for catch-up saccades in the plane of paired semicircular canals

Head Impulse Test – *Bedside Test Procedure*



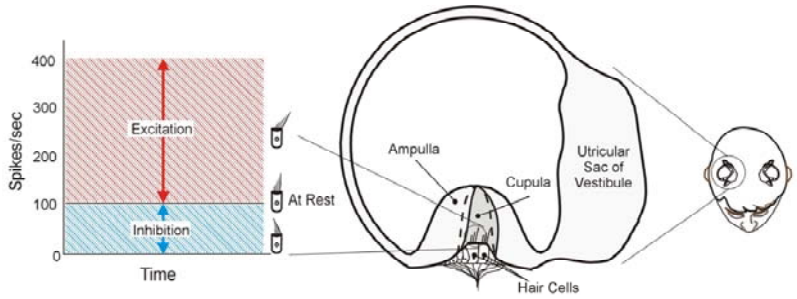
From Curthoys et al. (2010)

- Examiner stands in front of the patient and holds his or her head
- Patient is asked to look at a target straight ahead (examiner's nose?)
- The head is rotated right or left unexpectedly using small-amplitude high-velocity high-acceleration movements (head impulses)
- Normal individuals can maintain a steady gaze but patients with deficient VOR cannot keep up with high-velocity head turns and generate "catch-up" saccades after head impulses toward the damaged side

Head Impulse Test – *Limitations of Bedside Test*

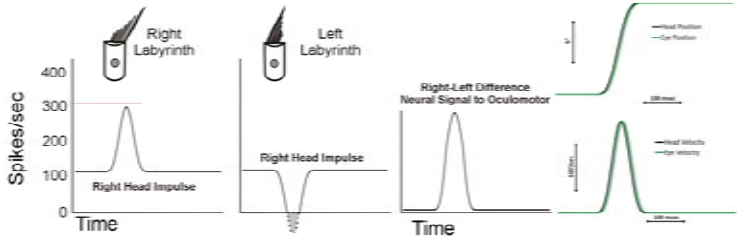
- Early experience with bedside head impulse testing produced mixed results
  - Results from caloric and head impulse tests did not always match
- Limitations
  - It is subjective – Must rely on the examiner's skills to detect catch-up saccades
  - The examiner has no feedback as to how well and how fast head impulses are delivered
- A better understanding of the underlying mechanisms is needed to improve clinical usefulness of the test

Head Impulse Test – *Mechanism*



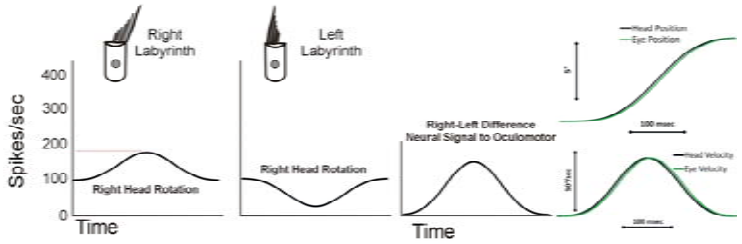
- There is an asymmetry between excitatory and inhibitory neural responses of each semicircular canal (greater dynamic range for excitation)
  - Excitation from tonic level of ~100 up to a maximum of ~400 spikes/sec
  - Inhibition from tonic level of ~100 down to a minimum of 0 spikes/sec

Head Impulse Test – *Normal Responses*



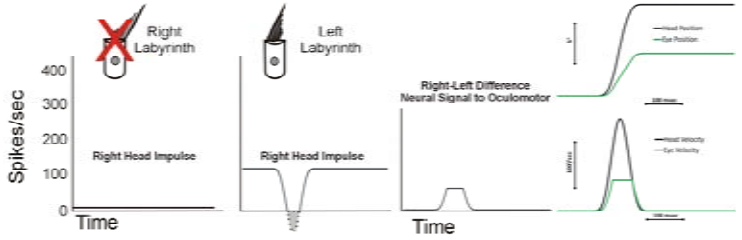
- For head impulses, inhibitory neural responses saturate quickly while the excitatory responses remain proportional to head velocity
  - Despite the asymmetry between excitatory and inhibitory responses, the overall input to the oculomotor system as well as the resulting eye movements remain symmetrical for right-left head impulses
  - Responses to head impulses are mediated primarily by one labyrinth!
  - *VOR Gain = Eye Move./Head Move. ≈ 1*

Head Impulse Test – *Normal Responses*



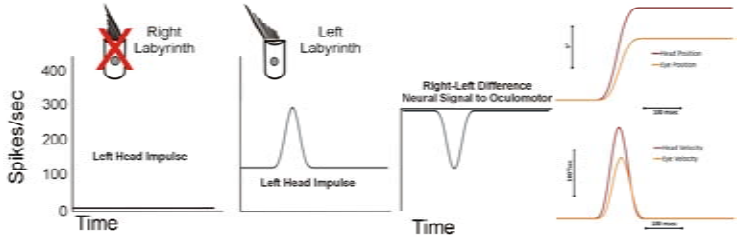
- For natural head movements, changes in the neural firing rates are proportional to head velocity
  - Neural responses from right and left are symmetrical for slow head movements
  - The signal to the oculomotor system is the difference between right and left neural responses
  - *VOR Gain = Eye Move./Head Move. ≈ 1*

Head Impulse Test – *Right Vestibular Lesion*



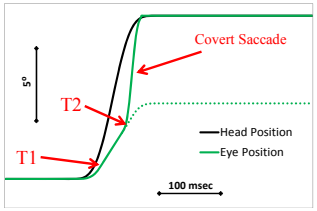
- For head impulses toward the side of lesion, the neural input to the oculomotor system is no longer proportional to head velocity
  - The resulting eye velocity does not match head velocity and the eyes fall short of target
  - *VOR Gain = Eye Move./Head Move. << 1* (decreases with increasing head velocity)

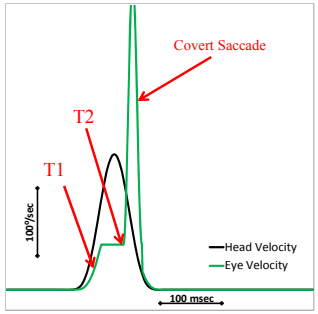
Head Impulse Test – *Right Vestibular Lesion*



- For head impulses away from the side of lesion, the neural input to the oculomotor system is reduced but to a lesser extent
  - 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)

Head Impulse Test – *Catch-Up Saccades*

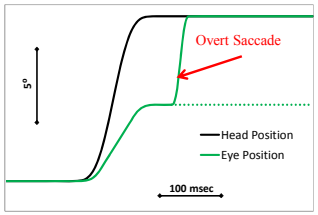


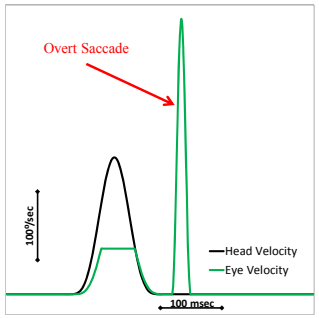


T1 = Decision to initiate saccade
T2 = Onset of actual saccade
T2 – T1 = Saccadic latency ≈ 70-150 msec

- Catch-up saccades that occur *during* head impulses are called <u>*covert*</u> saccades
- Covert saccades are practically impossible to detect without specialized equipment
- Covert saccades typically occur toward the end of head impulses because of the saccadic latency (time between initiation and onset of the saccade)
- It is not clear why some patients generate covert saccades while others do not
  - May be due to compensation levels, predictability of head impulses, or other yet unknown factors

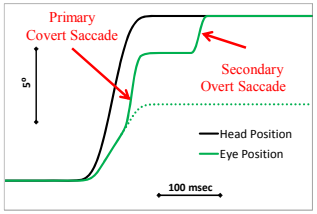
Head Impulse Test – *Catch-Up Saccades*

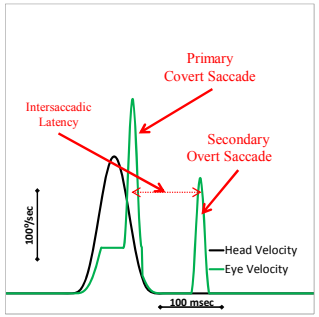




- Catch-up saccades reposition the eyes on the target
- Catch-up saccades that occur *after* head impulses are called <u>*overt*</u> saccades
- Overt saccades are visible and can be detected by an experienced examiner during the bedside test without any additional equipment

Head Impulse Test – *Covert Saccades*





- Covert saccades may not reposition the eyes exactly on the target if the head impulses are unpredictable
- In those cases, a secondary catch-up saccade, most likely an overt saccade, is needed to reach the target
  - The secondary saccade will usually be smaller but will have the same intersaccadic latency as the primary covert saccade
  - In the unlikely event of the primary covert saccade overshooting the target, the secondary catch-up saccade will be in the opposite direction

Head Impulse Test – *Objective Methods*

- Objective methods have been developed to identify covert saccades using the scleral search coil method, the gold standard for accurate measurement of high velocity eye movements (Weber et al, 2008)
- Alternative methods based on analyzing video images from high-speed cameras have been introduced because routine clinical use of the search coil method is cumbersome

Head Impulse Test – *Validity of Video Method*

- Validity and clinical usefulness of head impulse testing using the video measurement method depends on:
  - Accuracy of eye movement measurement methods
    - Typical VOR-Mediated eye movements can exceed 100^0/sec
    - High-speed high-resolution cameras are needed to differentiate slow and fast eye movements
    - The device must be compared with the search coil method
      - In at least one case, video recordings have been validated by comparing the results to the search coil method (Curthoys et al, 2010)

Head Impulse Test – *Validity of Video Method*

  - Accuracy of head movement measurement methods
    - Usually measured either through an apparatus worn by the patient or by tracking the movements of a fixed point on the head
    - Design and the fit of the apparatus can greatly affect the accuracy
    - Accuracy should be verified by comparing the results to measured values from a firmly affixed sensor such as one embedded in a bite-bar.

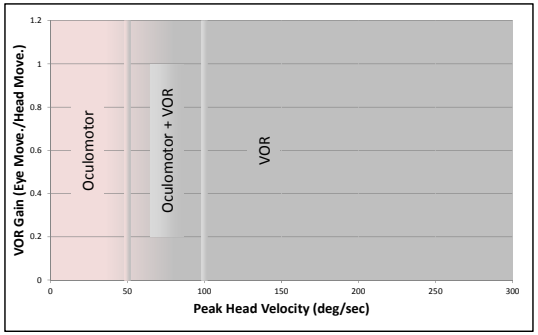
Head Impulse Test – *Validity of Video Method*

  - Examiner's ability to deliver appropriate head impulses
    - Examiner must be able to produce unpredictable head impulses that cover different head velocities
    - Device should be able to detect and reject inappropriate head impulses
    - Feedback to the examiner can improve performance
    - Monitoring patient's compliance with instructions can improve the test result

Head Impulse Test – *Criteria for Abnormality*

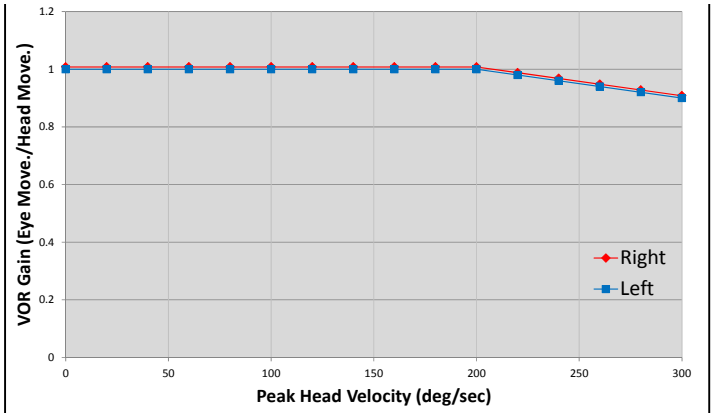
- Presence of catch-up saccades (overt and covert)
- VOR gain (slow eye movement / head movement where head/eye movements can be based on position, velocity, or acceleration)
- Gain asymmetry (difference between VOR gain for rightward and leftward head impulses)

Head Impulse Test – *Oculomotor and VOR Interaction*



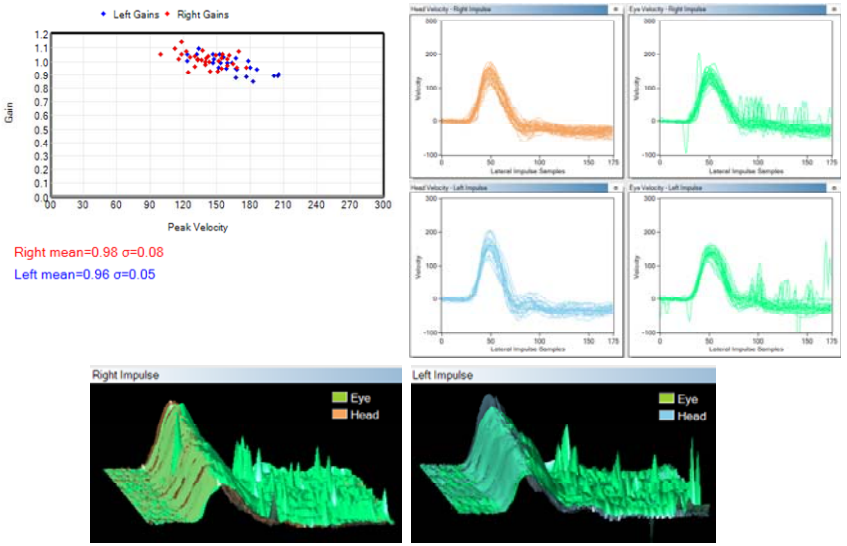
- Head impulse responses for head velocities below 50^0/sec are mediated entirely by the tracking (smooth pursuit) mechanism of the oculomotor system
- Both oculomotor and VOR mechanisms contribute to head impulse responses for head velocities between 50-100^0/sec (the ratio varies by age and other factors)
- Head impulse responses for head velocities above 100^0/sec are mediated entirely by the VOR

Head Impulse Test – *Normal*

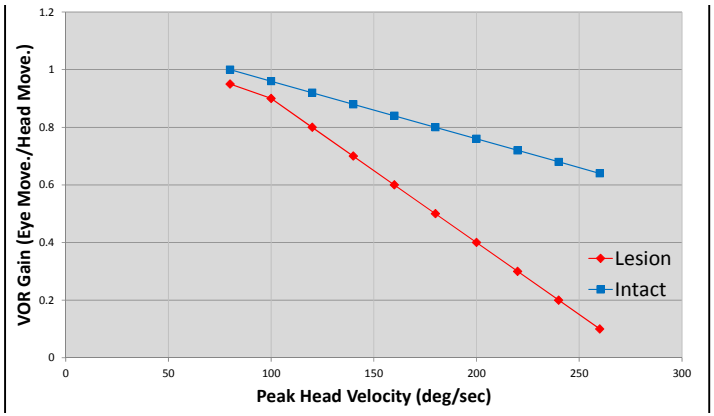


- VOR gain in normal individuals is approximately 1
  - Depends on whether the test is done in light or darkness
  - If in light, the gain is usually higher when the fixation target is close

Head Impulse Test – *Normal*

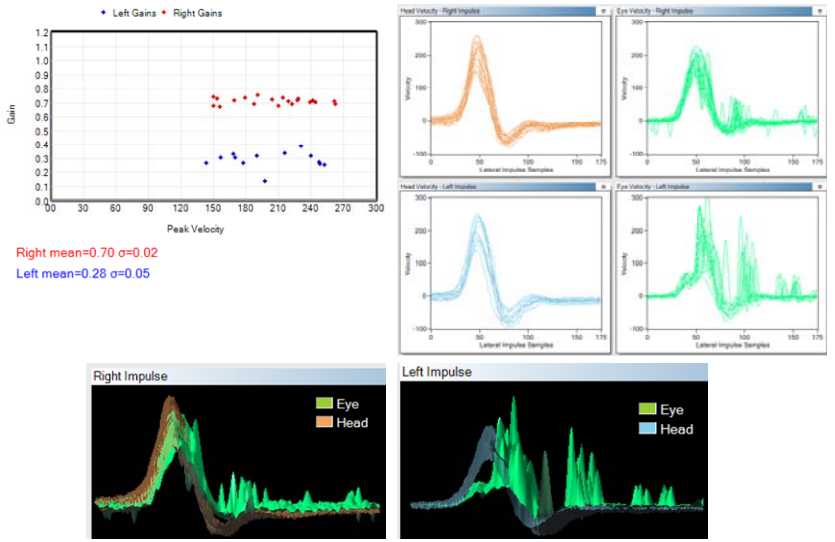


Head Impulse Test – *Unilateral Lesion*

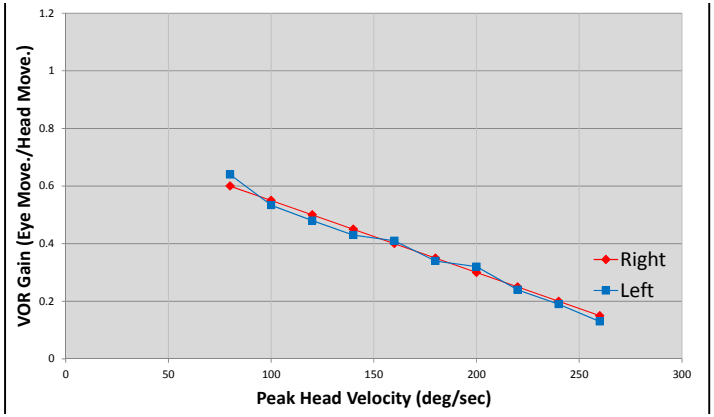


- VOR gain is reduced for head impulses both toward and away from the side of lesion but it is more significant for head impulses toward the side of lesion
  - VOR gains of higher than 1 have been reported during acute attacks of Meniere's

Head Impulse Test – *Unilateral Lesion*

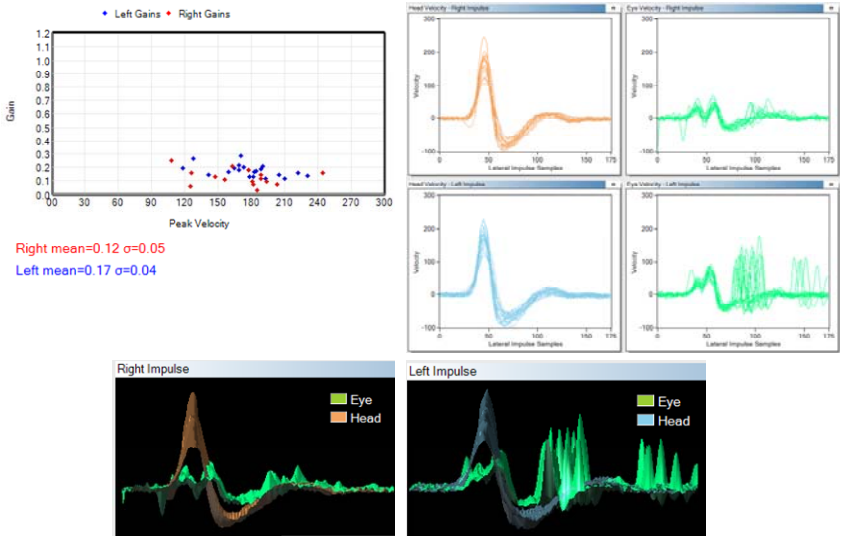


Head Impulse Test – *Bilateral Lesion*

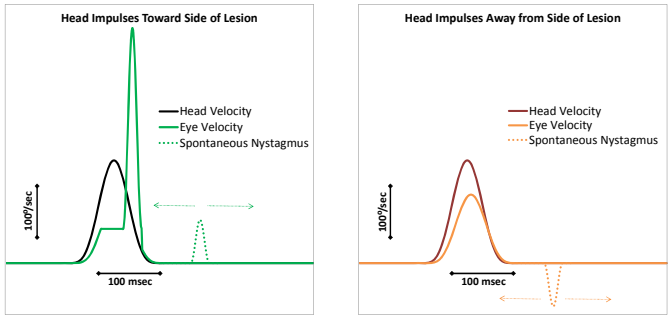


- Head impulse testing can be used in place of the rotation chair to assess patients with bilateral caloric weakness
  - Provides an objective measure for the extent of loss

Head Impulse Test – *Bilateral Lesion*

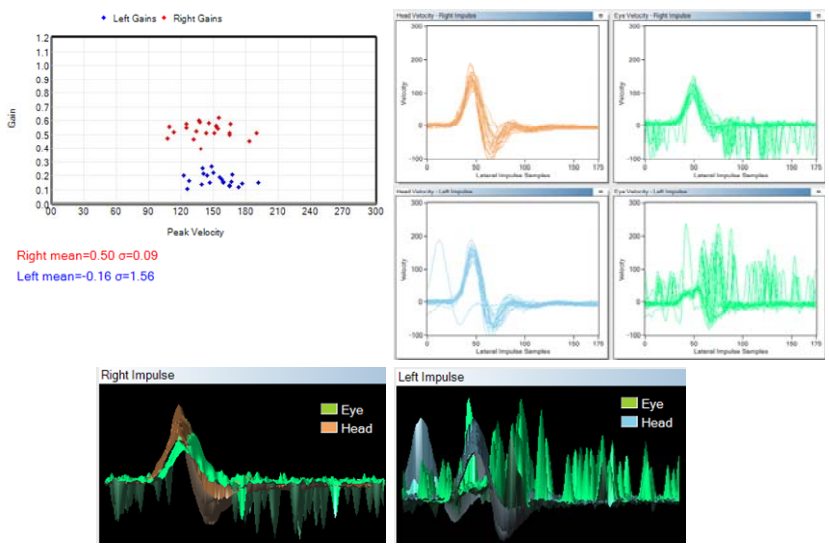


Head Impulse Test – *Spontaneous Nystagmus*



- Spontaneous nystagmus will appear as spikes in the eye velocity tracing
  - Right-beating nystagmus produces spikes in the same direction as eye movements following *left* head impulses
  - Left-beating nystagmus produces spikes in the same direction as eye movements following *right* head impulses
  - Unlike catch-up saccades, spikes for spontaneous nystagmus can occur before or after head impulses
  - For nystagmus that beats away from the side of lesion, spikes appear in the opposite direction of eye movements following head impulses toward the *intact* side

Head Impulse Test – *Spontaneous Nystagmus*



Head Impulse Test – *Compared to Caloric Test*

- Caloric
  - Independent assessment of right and left ears
  - Relative measure of right vs. left ear
  - Low-frequency
  - Limited to lateral canals
  - Not the natural mode of vestibular stimulation
  - Time-consuming
- Head Impulse
  - Independent assessment of right and left ears
  - Absolute responses of each ear!
  - Broadband
  - Can test vertical canals
  - Natural vestibular stimulus
  - Can be performed in few minutes

The results may not match because they are not the same test!
(similar to audiogram in different frequencies)

Head Impulse Test – *Compared to Rotation Testing*

- Rotation chair
  - Typically, chair velocities are not adequate to create VOR asymmetries
    - Even for high velocity rotations, head accelerations are far below those generated during head impulses
  - Is not as effective in independent assessment of each ear
  - Requires large space
- Active head rotation test
  - Does not provide independent assessment of each ear
  - May activate neck receptors thus providing results not directly mediated by VOR
  - Head velocities are lower than those in head impulse testing (Della Santina et al. 2002)

Head Impulse Test – *Compared to VEMPs*

- Both tests provide independent assessment of each ear
- Results from VEMPs and head impulse testing complement each other and provide a complete assessment of each vestibular system
  - VEMPs provide assessment of otoliths
  - Head impulse testing provides assessment of semicircular canals
  - Combining the results from both tests may distinguish between labyrinthine and vestibular nerve lesions

Acknowledgement

- Parts of this presentation are based on the work of Halmagyi, Curthoys, and their associates. See www.headimpulse.com for a complete list of references.

Head Impulse Test – *Clinical Usefulness*

- A simple test of VOR that can be performed quickly to independently assess all three semicircular canals in each ear over a wide range of head velocities
- In case of acute vertigo, can differentiate between cerebellar strokes and peripheral vestibular lesions (Newman-Toker et al., 2008)
- Can be used for serial testing such as in monitoring vestibulotoxicity
- Can be modified for testing children
- More widespread clinical studies are needed to verify and validate the objective methods of head impulse testing