PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Maggie Boorazanes, Au.D.
Product Manager, Vestibular

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT

Current Status of Vestibular Assessment

Typical VNG protocol consists of:

- Oculomotor testing – Central Lesion
- Positional Testing
  - Static Positional Testing – Typically non-localizing
  - Dynamic Positional Testing (Dix-Hallpike) – Peripheral Lesion
- Calorics – Peripheral finding (usually)

But we know VNG isn't perfect, as 60% of VNGs do not show abnormal findings

But what else is there?

- Since VNG isn't perfect, clinicians are embracing other methods of testing:
  - **vHIT**
  - **SHIMP**
  - VEMP
  - Rotary Chair
  - Posturography
  - SVV

otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATIONS OF VHIT AND SHIMP

Quick Acronyms/Vocabulary Review

VOR: **V**estibul**o**cular **R**eflex; keeps the eyes fixed on a target by moving eyes opposite to head movement (see next slide for more detail)

Saccade: fastest eye movement a patient can generate:

- for saccade testing during VNG, the clinician measures if the patient can generate a saccade to follow a provided stimulus
- during vHIT and SHIMP testing, the clinician measures if these movements are made in response to a fast head movement

HIMP: **H**ead **Imp**ulse test; any test where the patient's head is quickly moved to the side and the eyes are studied for presence of saccades

vHIT: **v**ideo **H**ead **I**mpulse **T**est; performing a HIMP with high-speed video goggles and measuring response of eyes versus head movement; target for this test is earth-fixed/stationary

SHIMP: **S**uppression **H**ead **Imp**ulse paradigm; a newer test that measures to confirm that the patient is generating saccades to keep their focus on a target that moves with the patient's head

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATIONS OF VHIT AND SHIMP

What is the VOR?

When testing a vestibular patient, we rely on studying eye movements to provide a "window" into the patient's vestibular system, and to do that, we study the Vestibulocular Reflex (VOR)

- A reflexive eye movement that stabilizes images on the retina by producing eye movement in the opposite direction of head movement (i.e., head moves right, eyes move left, image stays to center)
- Rotational movement is mediated by the semicircular canals.
- Eye movement must equal head movement in the opposite direction to maintain gaze. Normal VOR has a gain near 1.0.

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATIONS OF VHIT AND SHIMP

How Semicircular Canals Work With the Oculomotor System

Semicircular canals work as partners to determine eye movement: right lateral and left lateral canals; right anterior and left posterior canals (RALP); left anterior and right posterior canals (LARP).

Eye Muscles have Excitatory and Inhibitory Connections to the Semicircular Canals, so that when the semicircular canals detect movement of the head, the eyes move in the opposite direction to maintain gaze.

Semicircular Canal	Extraocular Muscles Excited	Extraocular Muscles Inhibited
Posterior (inferior)	Ipsilateral Superior Oblique (SO) Contralateral Inferior Rectus (IR)	Ipsilateral Inferior Oblique (IO) Contralateral Superior Rectus (SR)
Anterior (superior)	Ipsilateral Superior Rectus (SR) Contralateral Inferior Rectus (IR)	Ipsilateral Inferior Rectus (IR) Contralateral Superior Oblique (SO)
Horizontal (lateral)	Ipsilateral Medial Rectus (MR) Contralateral Lateral Rectus (LR)	Ipsilateral Lateral Rectus (LR) Contralateral Medial Rectus (MR)

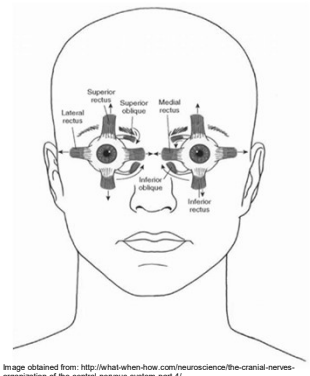


Image obtained from: http://what-when-how.com/neuroscience/the-cranial-nerves-organization-of-the-central-nervous-system-part-4/

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATIONS OF VHIT AND SHIMP

How Semicircular Canals Work With the Oculomotor System

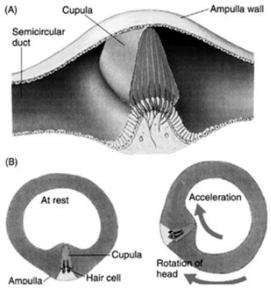


Image obtained from: http://www.d.umn.edu/~jfitzake/Lectures/DMED/InnerEar/VestibPhysiol/SemicircCanals.html

Patient is At Rest/Not Moving Head:

- The endolymph in the semicircular canals is not moving and not pushing the endolymph in the ampullae around the cupula to indicate movement.
- Nerve fibers in the semicircular canals fire at a resting rate of 100 spikes/second. This is essentially equal for both sides.
- No change from resting spikes/second means the eyes to not move.

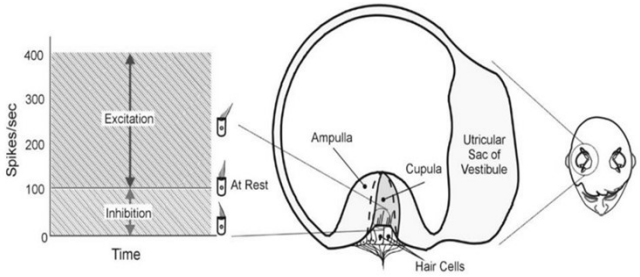
otometrics
a division of natus

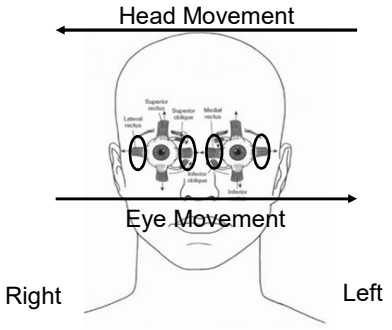
Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATIONS OF VHIT AND SHIMP

How Semicircular Canals Work With the Oculomotor System





Patient Turns Head (i.e., to the right):

- The endolymph in the semicircular canals moves to the left, pushing the endolymph in the ampullae around the cupula indicating movement.
- Nerve fibers on the right side (leading ear) firing at a higher rate (excitation) and at a slower rate on the left side (lagging ear; inhibition).
- The Extraocular Muscles receive this information, and move the patient's eyes to the left to maintain gaze to the center.

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

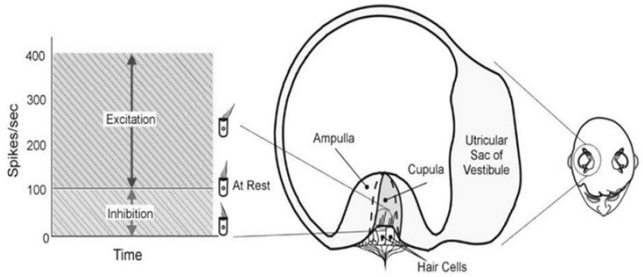
Why Don't Healthy Patients Make a Saccade?

Even for normal patients, there is a mismatch between the information from the excitatory side than the inhibitory side.

- For fast head movements to the right, there is more room for excitation on the right side, and the left side will saturate and not meet this level of performance.

Once the left side reaches 0 and saturates, the left labyrinth has no information of where the head is moving and can't control the eye movements.

For patients with normal vestibular function, this is not a problem since other labyrinth is providing most of the information to the brain.



otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Head Impulse: The Beginning

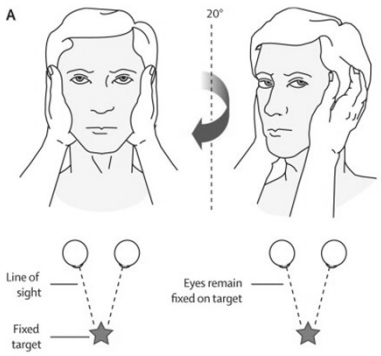
- Described by Halmagyi and Curthoys as a bedside test of the VOR.
- Examiner monitors eye movement as the head is thrust to the left or right. The patient is fixating on an object, typically the examiners nose.
- Horizontal head thrusts test the lateral semicircular canals.
  - Testing vertical canals is more difficult

First description of the head impulse test: Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. Arch Neurol 1988; 45(7):737-739.

otometrics
a division of natus

PHSYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Bedside Head Impulse Procedure- Normal



1. Tester tells the patient to keep their eyes fixed on the tester's nose.
2. Tester then sways patient's head from side to side, and then sharply to one side (i.e., right to left and then quickly and sharply to right).
3. Tester watches patients eyes closely.
4. When there is normal vestibular function, the patient's eyes stay fixed on the tester's nose.

Edlow, JA, Newman-Toker, DE, Savitz, SI.Diagnosis and initial management of cerebellar infarction. Neurology 2008; 7(10):951-962

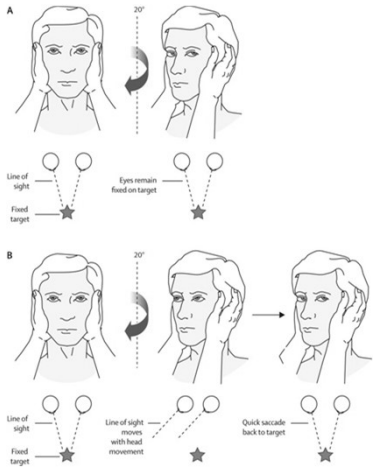
otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Bedside Head Impulse Procedure- Abnormal



1. Tester tells the patient to keep their eyes fixed on the tester's nose.
2. Tester then sways patient's head from side to side, and then sharply to one side (i.e., right to left and then quickly and sharply to right).
3. Tester watches patients eyes closely.
4. When there is Abnormal vestibular function, the patient's eyes move away from the testers nose, and then quickly shift to fix on the tester's nose (saccade).

Edlow, JA, Newman-Toker, DE, Savitz, SI.Diagnosis and initial management of cerebellar infarction. Nuerology 2008; 7(10):951-962

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

HIMP with Goggles (vHIT)

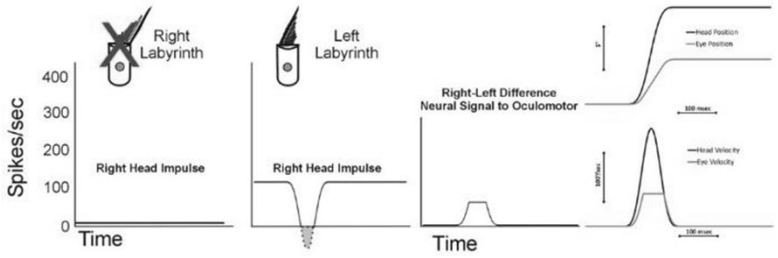
Testing procedure:

1. Patient is placed about 1 meter away from the wall.
2. A target is placed at the patient's eye level towards the patient's midline.
3. Goggles are placed on the patient and tightened.
4. Within software, adjust region of interest, adjust pupil detection, and then perform calibration.
5. Tester stands behind the patient, holding the top of the patient's head, and delivers quick, unpredictable head movements for the patient (about 20 times to each side/condition).
   - This is done in the plane of the lateral, anterior, and posterior semicircular canals
   - Conversely, bedside testing is typically done in the lateral plane
6. Tester reviews data provided by software.

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Why Does an Abnormal Patient Make a Saccade?



Example: The Right Lateral Semicircular Canal is damaged:

The patient will have two types of symptoms:
1) Static: vertigo, spontaneous nystagmus
2) Dynamic: The replica of head velocity is gone

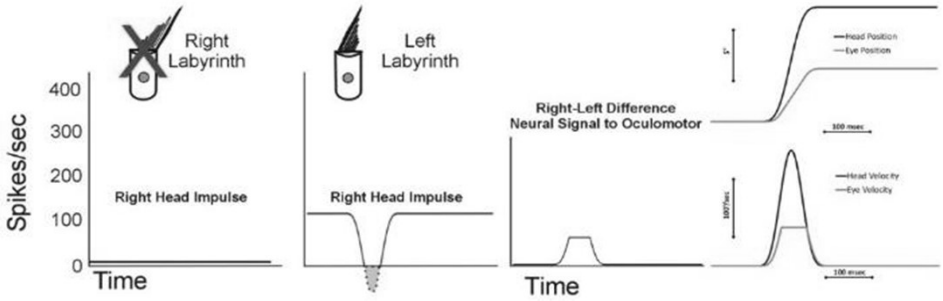
So now head moves here eyes move here and the eyes fall behind and short of the target. THIS IS ORIGIN OF CATCH UP SACCADE. Now VOR gain would be much less than 1.

Images courtesy of Kamran Barin, PhD

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Why Does an Abnormal Patient Make a Saccade?



Turning Head to Right (towards the lesion):
- In order to maintain focus on the target, the patient has to generate an additional eye movement to get to the target- a catch-up saccade

Images courtesy of Kamran Barin, PhD

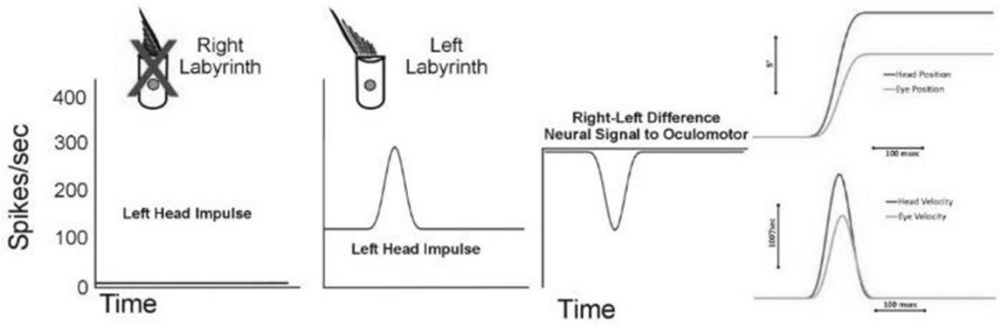
otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Why Does an Abnormal Patient Make a Saccade?



Turning Head to Left (away from the lesion):

- Still not normal.
- So if both result in abnormal eye movements, how do you know which side has the lesion??? Side with lower gain is the side of lesion.

Images courtesy of Kamran Barin, PhD

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Bedside Test Demonstration

Covert!

Animation courtesy of Kamran Barin, PhD

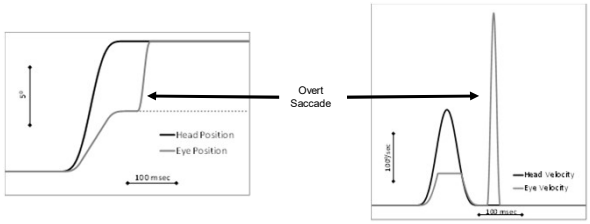
otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Types of Saccades- Overt Saccades



Catch-up saccades reposition the eyes on the target.

Overt Saccades:

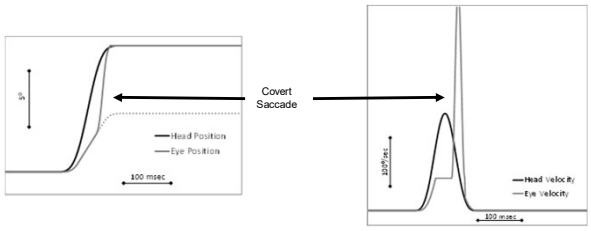
- Catch-up saccades that **occur *after* head impulses**
- Overt saccades are **visible** and **can be detected by an experienced examiner** during the bedside test without any additional equipment
- Timing: ~200 msec after the end of head motion (time between initiation and onset of the saccade)

Images courtesy of Kamran Barin, PhD

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Types of Saccades- Covert Saccades



Covert Saccades:

- Catch-up saccades that **occur *during* head impulses**
- Covert saccades are **practically impossible to detect** without specialized equipment
- Timing: ~70 msec to the end of head motion
- 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

Images courtesy of Kamran Barin, PhD

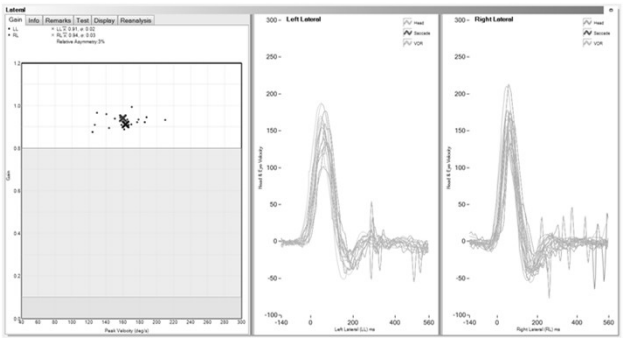
otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT

Normal vHIT Results



Normal Results

- Gain (comparison of eye and head movement)
  - Greater than 0.8 for Lateral
  - Greater than 0.7 for LARP/RALP
- Saccades
  - May have a few saccades but nothing significant

otometrics
a division of natus

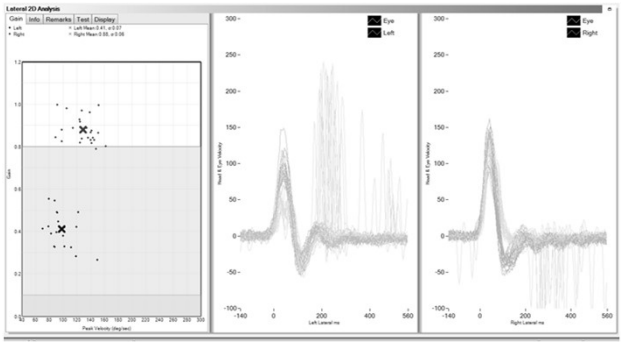
19

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT

Abnormal vHIT Results

Abnormal Results

- Gain (comparison of eye and head movement)
  - Less than 0.8 is abnormal for Lateral
  - Less than 0.7 is abnormal for LARP/RALP
    - 0.1 to 0.8 if unilateral loss for Lateral
    - 0.1 to 0.7 if unilateral loss for LARP/RALP
    - Less than 0.1 if bilateral loss*** Not always the case, look for catch-up saccades***
- Saccades consistently present:
  - Timing:
    - Covert:~70 msec to the end of head motion
    - Overt: within ~200 msec after the end of head motion
  - Size: Saccades that are substantially smaller than the peak head velocity should not be considered as catch-up saccades
  - Consistency: Presence of consistent catch-up saccades should be considered abnormal even when the VOR gain is within normal limits



otometrics
a division of natus

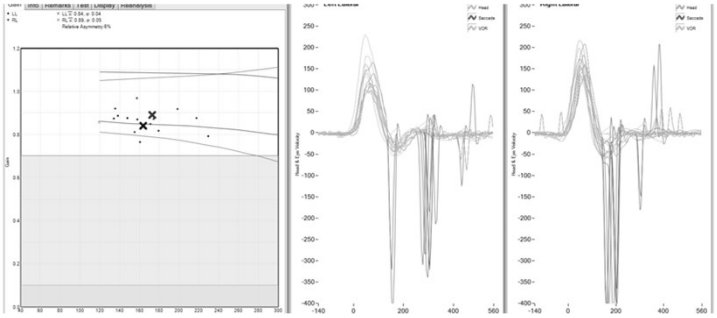
20

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

SHIMP Introduction



- A relatively new testing paradigm published by MacDougall, McGarvie, Rogers, et al. in 2016
- Research on this is emerging, and limited
- During SHIMP, patient's follow a moving target with their eyes from a head-mounted laser as the head is quickly moved in the horizontal plane
- The basic physiology for HIMP and SHIMP is the same

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

SHIMP Introduction

- How to test:
  - Patient instructed to follow a moving target (i.e., laser projected from goggle)
  - Tester delivers lateral head impulses in a randomized fashion
- What is measured:
  - VOR Gain (should be similar between HIMP and SHIMP)
  - Size (velocity) of the corrective saccade

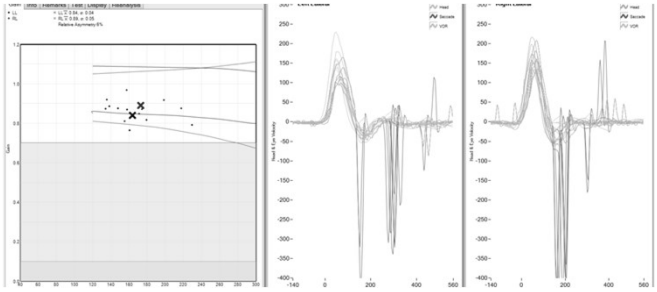
otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

SHIMP Testing- Normal Patients

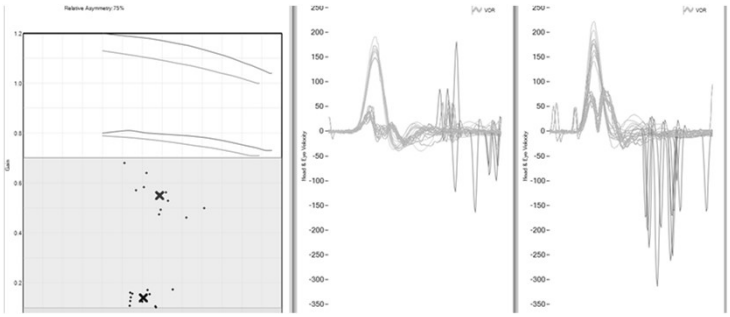


- Healthy patients show a large **anticompensatory** saccade after head movement
  - During the head movement, the eyes move to the opposite direction (ex: patient's head is moved left, eyes move to the right)
  - Healthy subjects do not suppress their VOR in the early stages of head movement (~80 msec)
  - Gaze is driven by the VOR from the target that is moving with their head
- Saccade size is key!
  - Healthy subjects make big saccades because they have more distance to catch-up

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

SHIMP Testing- Abnormal Patients



- Patients with vestibular loss do not show any corrective saccades
  - During the head movement, the VOR is absent, so the eyes are not moved to the opposite direction, they move with the patient's head
  - At the end of the head movement, the eyes are still on the target (because the target has moved with the head movement), so no saccade is made
- Saccade size is key!
  - Patients with vestibular loss show small saccades or no saccades (i.e., Unilateral Vestibular Loss)
  - Interpret size with care, size can be impacted by factors such as:
    - Amount of overshoot in the head impulse
    - Peak head velocity of the head impulse
    - Predictability of the head turn
    - Duration of the head impulse, etc.

otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGIC APPLICATION AND BASIS OF VHIT AND SHIMP

vHIT versus SHIMP

Factor	vHIT	SHIMP
Target	Earth-fixed (mounted to wall)	Head-fixed (projects from goggle)
Stimulus	Brief, passive head turn in the lateral and anterior planes	Brief, passive head turn in the lateral plane
Can be performed	At bedside with no equipment With vHIT goggles	At bedside with no equipment With vHIT goggles
Expected result in normal	Gain >0.8; few saccades	Patient has consistent, large anticompensatory saccades
Expected result with vestibular loss	Gain <0.8 lateral, <0.7 LARP/RALP; consistent presence of saccades	Gain is similar to vHIT; few small saccades, or absence of saccades
Overt Saccades	Yes; with bedside testing or with vHIT goggles	Anticompensatory, overt saccades with bedside testing or vHIT goggles
Covert Saccades Measured	Only with vHIT goggles	No

otometrics
a division of natus

25

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Why Use SHIMP Testing?

Bilateral Loss and Unilateral Loss:

- The presence of catch up saccades indicate vestibular function whereas no catch-up saccades indicate vestibular loss.

- Implications for vestibular rehab

Keep in mind, this is a relatively new testing paradigm, and there is still much to learn . . .

otometrics
a division of natus

26

Presented in cooperation with

CONTINUED

PHYSIOLOGIC BASIS AND APPLICATION OF VHIT AND SHIMP

When to use vHIT and SHIMP?

- Use as entry point of vestibular assessment (start with this before a VNG to determine need for calorics)
- Cochlear implant assessments
- Use in conjunction oVEMP/cVEMP to assess all portions of the vestibular system
- Use for pediatric patients and others unable to tolerate traditional testing
- Vestibulotoxicity monitoring (i.e., intratympanic gentamicin injections)
- Can be used for stroke detection in ER (Johns Hopkins AVERT study, HINTS protocol)
- Enhances ability to assess more of the vestibular system (vertical canals; more subtle abnormalities)
- Knowing where lesion is (and how extensive) may have implications for rehabilitation and recovery expectations (especially for SHIMP)
- Rehabilitation outcomes

- So much more to uncover… remember the clinical launch of OAE's?

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Why Use Equipment?

- ICS Impulse can:
  - Identify covert saccades
  - Validates that head impulse is performed properly
  - Documents prevalence and consistency of saccades, as well as presence of covert saccades
  - Objective analysis with normative data
  - Better patient comfort during test
  - Otosuite Vestibular also calculates gain for both vHIT and SHIMP

- Other benefits to equipment usage:
  - Sensitivity and specificity are 95% for the ICS Impulse
  - Reduction in false negatives (ID patients as normal who are truly abnormal)
  - Better, more consistent patient care across providers

otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Does the Type of Goggle Used Matter?





VNG Goggles- Not recommended

- Standard VNG goggles are too bulky- monocular ICS Impulse goggles are optimized for vHIT testing
- Cannot detect some saccades

Rotary Chair Testing- Not recommended

- All issues associated with VNG goggles
- Cannot reach sufficient velocity
  - 10 to 80 deg/sec
  - Need 100 to 250 deg/sec for proper head impulse

otometrics
a division of natus

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Conclusion

- VNG is a reliable, but limited method of testing patients
- vHIT and SHIMP provide information, that VNG cannot provide, about semicircular canal function
- While visual observation has been used for decades, vHIT is a much more reliable tool to enhance clinical practice
- Technology, like ICS Impulse, is driving changes in understanding of physiology of the vestibular system- we are learning there is still so much to learn

otometrics
a division of natus

Presented in cooperation with

CONTINUED

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND SHIMP

Conclusion

- Questions?

PHYSIOLOGICAL BASIS AND APPLICATION OF VHIT AND VEMP

References

Edlow, JA, Newman-Toker, DE, Savitz, SI. Diagnosis and initial management of cerebellar infarction. Nuerology 2008; 7(10):951-962

Halmagyi GM, Chen L, Mac Dougall HG, Weber KP, McGarvie LA, Curthoys, IS (2017). The video head impulse test. Front. Neurol. 8:258.

Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. Arch Neurol 1988; 45(7):737-739.

Halmagyi GM, Weber KP, Aw ST, Todd MJ, Curthoys IS (2008) Impulsive testing of semicircular canal function. In: Kennard C, Leigh RJ (eds) Using Eye Movements as an Experimental Probe of Brain Function. Progress in Brain Research, volume 171, chapter 3.6, pp 187-194.

MacDougall HG, McGarvie LA, Halmagyi GM, Rogers SJ, Manzari L, Burgess AM, Curthoys IS, Weber KP (2016). A new saccadic indicator of peripheral vestibular function based on the video head impulse test. Neurology 2016; 87: 1-9.

MacDougall HG, Weber KP, McGarvie LA, Halmagyi GM, Curthoys IS (2009). The video head impulse test: Diagnostic accuracy in peripheral vestibulopathy. Neurology 73 (14): 1134-1141.

McCaslin D (2013). Electronystagmography and Videonystagmography.

Weber KP, Aw ST, Todd MJ, McGarvie LA, Curthoys IS, Halmagyi GM. Head impulse test in unilateral vestibular loss: vestibulo-ocular reflex and catch-up saccades. Neurology 2008; 70(6):454-463.

otometrics
a division of natus