# Current Trends in Vestibular Assessment

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## Disclosures

I am an employee of Micromedical Technologies and Interacoustics.

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## Current Trends in Vestibular Assessment

Agenda:

- cVEMP and oVEMP Assessment
- vHIT Introduction
- Lateral vs. Vertical vHIT Assessment
- Current Trends in Research and Clinical Applications
- Streamlining Your Vestibular Evaluations (VNG, Rotary Chair, VEMP and vHIT)

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## Statistics – Dizziness and Vertigo

- As many as 35% of adults aged 40 and older in the U.S. have experienced some form of vestibular dysfunction

Agrawal Y, Carey JP, Della Santina CC, Schubert MC, Minor LB. Disorders of balance and vestibular function in US adults. Arch Intern Med. 2009;169(10): 938-944.

- Another 4% of adults report a chronic problem with balance

National Institute on Deafness and Other Communication Disorders (NIDCD). Strategic Plan (FY 2006-2008).

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## Statistics – Dizziness and Vertigo

- 80% of people aged 65 years and older have experienced dizziness

Ator GA. Vertigo - Evaluation and Treatment in the Elderly

- BPPV is the cause of approximately 50% of dizziness in older adults

Fife TD, Iverson DJ, Lempert T, Furman JM, Baloh RW, Tusa RJ, Hain TC, Herdman S, Morrow MJ, Gronseth GS. Practice parameter: therapies for benign paroxysmal positional vertigo (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurol. 2008;70:2067–2074.

- Pediatric vestibular disorders are receiving increasing attention from clinicians as an overlooked problem (estimated 6-8% of children)

Rine RM. Growing evidence for balance and vestibular problems in children. Audiological Med. 2009;7(3):138-142

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## Statistics – Dizziness and Vertigo

- Overall, vertigo from a vestibular problem accounts for a third of all dizziness and vertigo symptoms reported to health care professionals

Neuhauser HK, Radtke A, von Brevern M et al. Burden of dizziness and vertigo in the community. Arch Intern Med. 2008;168(19):2118–2124.

- Dizziness accounts for an estimated 5% of all primary care clinic visits

Robert E. Post, MD, Virtua Family Medicine Residency, Voorhees, New Jersey. Lori M. Dickerson, PharmD, Medical University of South Carolina, Charleston, South Carolina. *Am Fam Physician*. 2010 Aug 15;82(4):361-368.

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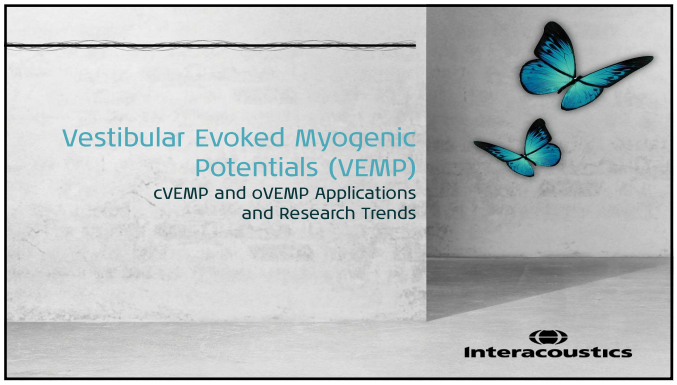


## Vestibular Evoked Myogenic Potentials (VEMP)

What is VEMP?

Definition: A myogenic response recorded from muscles of the neck or eyes, reflecting otolithic (saccule and utricle) vestibular function in response to high-level acoustic or vibratory stimulation

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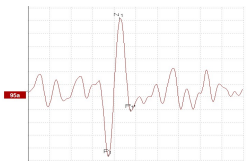
## Vestibular Evoked Myogenic Potentials

First VEMP recordings date back to early 1960s, but Colebatch et al. (1994) was the first to report VEMP as recorded from the neck muscles



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## VEMP Overview

- Investigates otolith function
- Provides quantitative separate ear information about otolith/vestibular nerve function
- Doesn't make the patient dizzy
- Can be performed on existing evoked potential equipment (AMLR)
- Quick test (10-15 minutes)

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## VEMP Overview

- cVEMPs
  - Cervical Vestibular Evoked Myogenic Potentials
  - Saccule / inferior nerve function
  - Sternocleidomastoid (SCM) muscle
- oVEMPs
  - Ocular Vestibular Evoked Myogenic Potentials
  - Utricle / superior nerve function
  - Extra-ocular muscles (inferior oblique)

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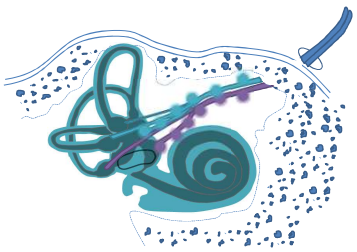
## VEMP Overview

oVEMP records the function of the utricle and superior vestibular nerve

cVEMP records the function of the saccule and inferior vestibular nerve



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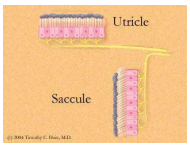
## VEMP Overview

Otolith Overview:

- The otolithic organs sense motion according to their orientation
- The utricle is largely horizontal in the head
- The saccule is largely vertical

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## VEMP Overview

Innervation of the vestibular system:

- Superior Vestibular Nerve:
  - Anterior Canal
  - Horizontal Canal
  - Utricle
- Inferior Vestibular Nerve:
  - Saccule
  - Posterior Canal

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## VEMP Overview

Otolith Overview:

The otolithic organs sense motion and initiate collic, spinal and ocular reflexes

- Vestibular Collic Reflex –VCR
  - Maintains head stability
- Vestibular Spinal Reflex –VSR
  - Maintains body posture/stability
- Vestibular Ocular Reflex –VOR
  - Otolith ocular reflexes (OOR)/translational VOR
  - Maintains visual acuity during linear accelerations

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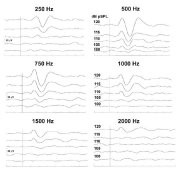
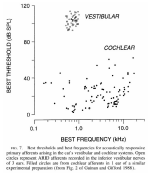
## VEMP Overview

- Otoliths respond to loud sounds
- Otoliths respond to low frequency sounds, i.e. 500Hz




Akin FW, Murnane OD, Proffitt TM, Akin TM. (2003).




Guinan and Gifford, 1988

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## VEMP Overview

- Both oVEMP and cVEMP response amplitudes are known to decrease with age, while thresholds increase with age
- Piker et al (2013) reported that optimal stimulus frequency changes with age. Frequency tuning tends to increase with advanced age.
- 500 Hz may not be ideal for all age groups
- Use 750 Hz or 1000 Hz tone bursts for as necessary when testing a patient over age 60
- oVEMP decreases after age 80

Piker EG, Jacobson GP, Burkard RF, McCaslin DL, Hood LJ (2013). Effects of age on the tuning of the cVEMP and oVEMP. *Ear Hear 34;* 65-73.

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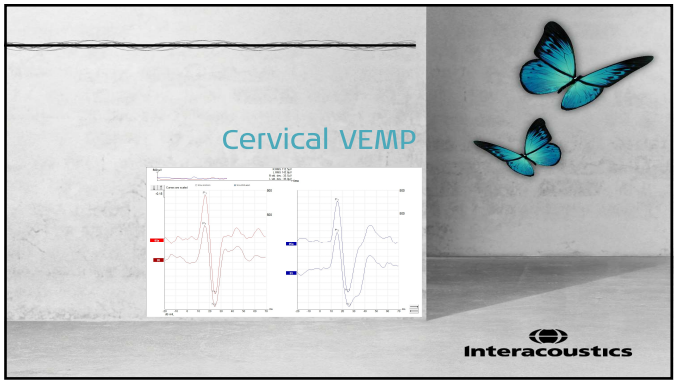

## cVEMP

- The VCR 'output' in the SCM is inhibitory
- It is considered a reflex, rather than a true sensory EP (Burkhard & Shepard, 2013)
- Response (VCR) can be measured in tonically contracted SCM muscles
- Presence of response is **very** dependent on myogenic activity (more details later)
- Not dependent on hearing sensitivity (unless conductive loss)

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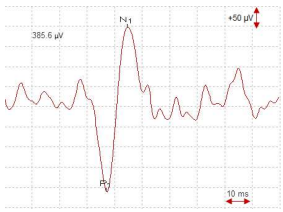
## cVEMP

- Response amplitude is measured from P13 to N23 (also referred to as P1, N1)
- Large responses compared to other auditory evoked potentials
- Typical response is ~50 to 300µV, depending on test protocol, but can be as large as 500µV

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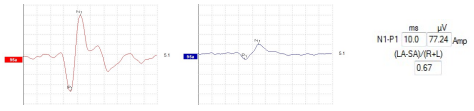
## cVEMP

- Measure peak to trough
- Compare L to R (similar to calorics)
- Normal ratio R:L .33-.47 range (Gans & Roberts)
- Neurological impairment can affect latency

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## Calculating VEMP Asymmetry

$$\text{Asymmetry Ratio} = \frac{\text{Amplitude (L)} - \text{Amplitude (R)}}{\text{Amplitude (L)} + \text{Amplitude (R)}} \times 100 = \%$$

- Amplitude is measured from P1 to N1
- Ratio of greater than .33 is clinically significant
- Many devices will automatically calculate asymmetry for you after you mark both sides and set as VEMP partners

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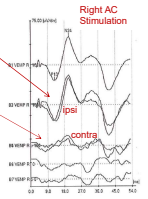
## cVEMP

- It is an ipsilateral response
- Contra waveform will show significantly reduced amplitudes
- cVEMP responds best to AC stimulation (high intensity)

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## cVEMP Recording Parameters

| | |
|---|---|
| Amplifier gain | 800 µV (66 dB)<br>~2500 – 5000x |
| Epoch length | ~100 msec<br>20msec pre-stimulus |
| Sweeps per average | ~80-120 is usually sufficient |
| Waveform replication | x1 minimum |
| Artifact rejection | Off (this is a **MUST**) |

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## cVEMP Stimulus Characteristics

| | |
|---|---|
| Stimulus type | 100 µsec click, or, 500 Hz tone burst, 6-10 ms duration, 2-1-2 cycle (Blackman gating) |
| Transducer | ER3a insert earphone or bone conductor |
| Rate | ~5.1/second |
| Intensity | +5 dB relative to VEMP response threshold (usually 90-100 dB nHL) 97dB is often used |

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## cVEMP Recording Parameters

| | |
|---|---|
| Recording Condition | Seated in comfortable reclining chair, or, lying on a table |
| Inverting (reference) electrodes | Ipsi & contra upper 3rd of SCM muscles |
| Non-inverting (active) electrode | Chin, sternum, or high forehead |
| Ground electrode | Forehead |
| Filtering | HP: 10 Hz 6/oct<br>LP: 750 Hz |

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## cVEMP Recording Parameters

Effect of Inverting Electrode Placement on waveform characteristics:

- Electrode placement on SCM will affect whether the waveform is displayed as positive or negative
- Invert Waveforms option: Eclipse EP25 General Setup configuration allows for option to invert VEMP waveforms on display


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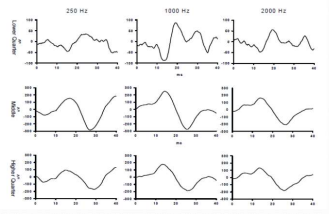
## cVEMP Recording Parameters

Inversion of Polarity:




Lewis, A Mustain, W, Youguo, X, Eby, T, Wu, Z (2010)

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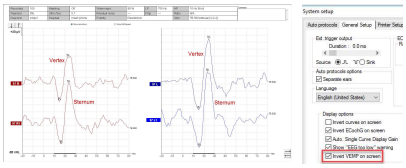
## cVEMP Recording Parameters

Inversion of Polarity:




- Polarity will not change based on active electrode placement, only reference placement
- Polarity will invert if selected in setup

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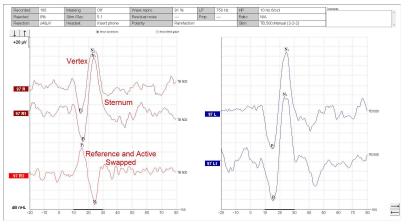
## cVEMP Recording Parameters

Inversion of Polarity:

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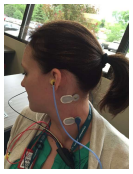
## cVEMP Recording Parameters

Effect of Inverting Electrode Placement on waveform characteristics:

- Electrode placement on SCM will also affect latency
- It's important to place the electrode in the upper 1/3 of the SCM to avoid polarity inversion, but not too high
- When too high up on the SCM, latencies will be prolonged



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## cVEMP Considerations

- Before cVEMP test check middle ear status
  - Even 3dB conductive component can cause AC response to disappear!
- Test involves flexing SCM, therefore check for neck or spinal problems before starting
  - Muscle movement disorders are a contraindication

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## cVEMP

- Ask patient to lift head when hearing the loud stimulus
  - Ipsilateral contraction (lift and turn away from stim ear)
  - Myogenic activity feedback
- 2-3 traces performed to validate response repeatability
- Two control traces can also be performed:
  - 1 x lifting head with no stimulus (to differentiate from background myogenic activity)
  - 1 x NOT lifting head and playing stimulus (the post auricular muscle response test)

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## cVEMP Recording Methods

Always use this method as long as the patient can perform the task

*Position A: Notice how head is raised, and can be turned away from the side of stimulation throughout the test.*

Alternative method

*Position B: An alternative patient position which many patients accept more easily. Muscle must be with strong tonus.*

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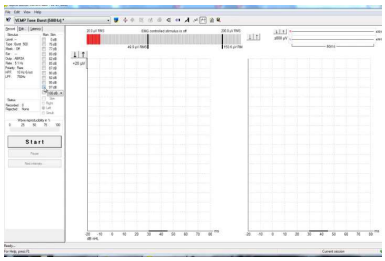
## cVEMP




Data Collection Video

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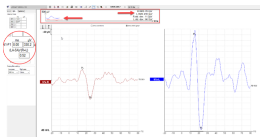
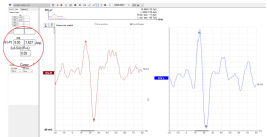
## cVEMP – EMG Scaling

EMG Scaling (Post-Data Collection Rectification):

- Produces more accurate amplitude asymmetry analysis, regardless of variable muscle contraction
- More robust than just using patient monitor



Not scaled – 52% amplitude asymmetry



Scaled – 9% amplitude asymmetry

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## cVEMP

Advantages:

- Objective response
- Reflects unilateral function of an otolithic end organ
- Can provide a valuable diagnostic measure alongside other vestibular assessments

Disadvantages:

- Requires patient's active cooperation
- Difficult to record in patients with cervical problems (i.e. reduced muscle mass due to aging)
- Susceptible to middle ear pathologies

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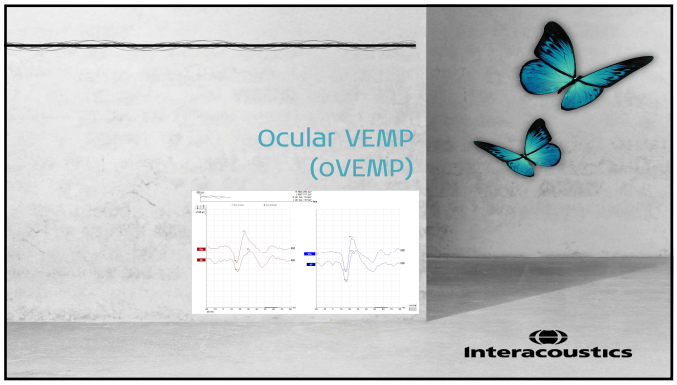
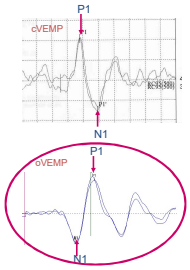



## oVEMP

- The oVEMP waveform is negative/positive (i.e. going from nothing to something) instead of positive/negative (i.e. going from something to nothing)

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## oVEMP

- Represents the synchronous evoked extraocular muscle activity associated with the VOR.
  - Does not represent movements of the eyes (i.e. is not EOG)
- Extra-ocular muscles have properties that allow them to be activated with precision at short latencies for fine motor control of eye movements
- The response is driven by the otoliths (primarily utricle, but saccule may also partially contribute)

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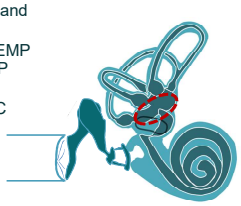
## Justification for Origin of oVEMP

- Neural connections between saccule and eye muscles are weak
- In superior vestibular neuritis, the oVEMP was absent, and the ipsilateral cVEMP was normal (Manzari et al, 2010)
- Acoustic stimuli activate very few SSC neurons, but many in the otoliths
- Connections between utricle and eye muscles are strong
- In inferior vestibular neuritis the ipsilesional cVEMP is absent and the oVEMP is present (Manzari et al, 2010)



Hamagyi & Curthoys (2000), Curthoys (2010) Curthoys (2012)

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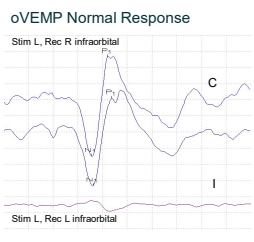
## oVEMP

- In response to 500 Hz tone burst AC or BC
  - N1: ~10 msec
  - P1: ~15 msec
- Contralateral response occurs slightly earlier and is larger than ipsilateral response (contralateral pathway is faster)

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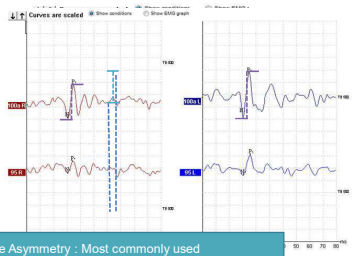
## oVEMP Analysis



Latency:

@ 500 Hz published studies suggest
N1 Mean 12.8 + 2.47 (+2SD)
P1 Mean 15.9 +3.02 (+2SD)
Piker et al (2011)

Amplitude :
@ 500 Hz published studies suggest:
P1 –N1 7.0 µV
Piker et al (2011)

Clinics are encouraged to collect their own norm data

L/R Amplitude Asymmetry : Most commonly used
@ 500 Hz published studies suggest
P1 N1 difference = 33% Piker et al (2011)

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## oVEMP Stimulus Characteristics

| | |
|---|---|
| Stimulus type | 500 Hz tone-burst, 2-1-2 cycle, Blackman gating |
| Transducer | ER3a insert earphone or bone conductor |
| Rate | ~5.1 second |
| Sweeps | 150-300 |
| Intensity | +5 dB re: VEMP response threshold (usually 90-100 dB nHL) Typical is 97 dB |

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## oVEMP Recording Parameters

| | |
|---|---|
| Electrode locations | Infra-orbital (non-inverting), chin or forehead (inverting), Fpz (ground) |
| Gain | 400 µV (72 dB) 100,000x (versus 800µV for cVEMP) |
| Recording Epoch | 100+ msec including a 10-20 msec prestim period |
| Gaze | Supra-medial (up, midline) |
| Artifact Reject | Off – same as cVEMP |
| Filtering | HP: 10 Hz 6/oct<br>LP: 750 Hz |

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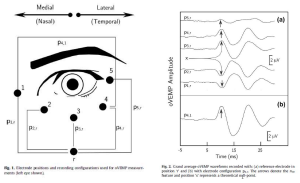
## oVEMP Electrode Positioning

- Just as with cVEMP, inverting electrode placement does matter
- Position the electrodes slightly laterally beneath the eye
- Right electrode under left eye to record the contralateral response
- Avoid null point (center)




Sandhu JS, George SR, Rea PA (2013). The effect of electrode positioning on the oVEMP to air-conducted sound. *Clinical Neurophysiology 124;* 1232-1236.

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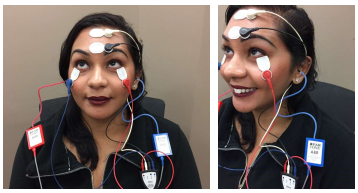
## oVEMP Electrode Positioning

- Inverting (reference) electrodes placed under the eyes
- Non-inverting placed on forehead or near bridge of the nose
- May produce slightly larger amplitudes



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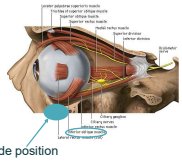
## oVEMP Recording Methods

- Inferior Oblique muscle is innervated by CNIII
- Elevation of the eyes places the Inferior Oblique muscle close to the recording electrode
- Gaze upward at least 30º - 40º



Reference electrode position

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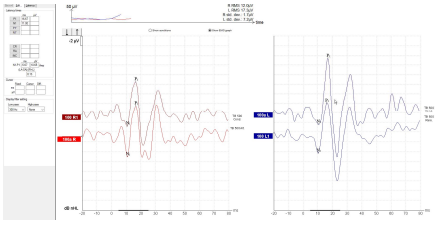
## oVEMP Sample Recording



Right amplitude = 10.65μV
Left amplitude = 13.81μV
Amplitude asymmetry = 13%

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## oVEMP

Advantages:

- Objective response of utricular function
- Can be obtained in older patients (up to age 80)
- Has been reported to have higher sensitivity than cVEMP for identification of SSCD

Disadvantages:

- Requires patient's active cooperation
- Doesn't respond as well to air-conducted stimuli
- Smaller response than cVEMP and may be unrecordable in as many as 20% of normals (AC stimuli)

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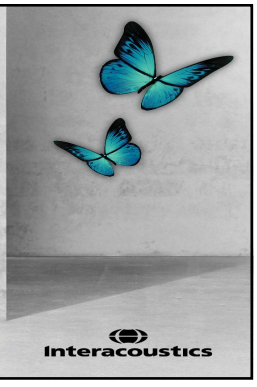
## Pathological VEMP Results

Interpreting the Data



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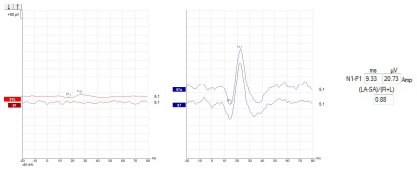
## VEMP in Pathology

Example of saccule/inferior nerve dysfunction on the right

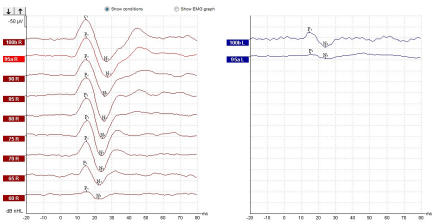


## VEMP in Pathology

- Both cVEMP and oVEMP peak-to-peak amplitudes can be useful in detecting SSCD (Hunter et al, 2017)
- Suprathreshold oVEMP n10 amplitudes may provide an efficient single-step approach to diagnosis (Janky et al, 2013)
- Another approach is to look for the presence of oVEMP n10 response to AC stimuli at 4000 Hz to identify SSCD (Manzari et al, 2013)
- High-resolution CT remains the gold standard for SSCD diagnosis (Hunter et al, 2017)

## VEMP in Pathology

Clinical Example of Superior Canal Dehiscence:



cVEMP Example

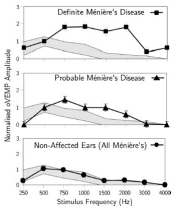
## VEMP in Pathology

Endolymphatic Hydrops – Ménière's Disease

n= 8

n= 4

n= 8




- Several researchers have shown that there is a shift in maximal response to higher ferequencies in patients with MD (Sandhu et al 2012)
- Holds true for o-VEMPs and c-VEMPs

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## VEMP in Pathology

Other interesting research:

- oVEMP abnormalities correlate highly with BPPV (Singh, 2016)
  - Peak to peak amplitudes was significantly smaller in the BPPV affected ears than unaffected ears and healthy controls
- Patients with vestibular migraines have a higher rate of oVEMP abnormalities (Zaleski, 2015)
- oVEMP is abnormal in 90% of patients with otolith impairment (Murofushi et al, 2012)

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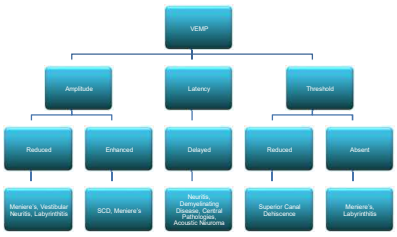
## VEMP Diagnosis Guideline




Adapted from: Hain, TC. http:\www.dizziness-and-hearing.com. 27 Dec 2006 <http:\www.dizziness-and-balance.com\images\master-ear.jpg>.

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## VEMP Summary

Clinical Applications:

- Provides additional information to aid in diagnosis and piece together pathophysiology
- Good test to use for pediatric cases
- Useful in helping to identify:
  - Inferior Vestibular Nerve Dysfunction
  - Superior Canal Dehiscence
  - Meniere's Disease
  - Even Vestibular Migraines in some instances

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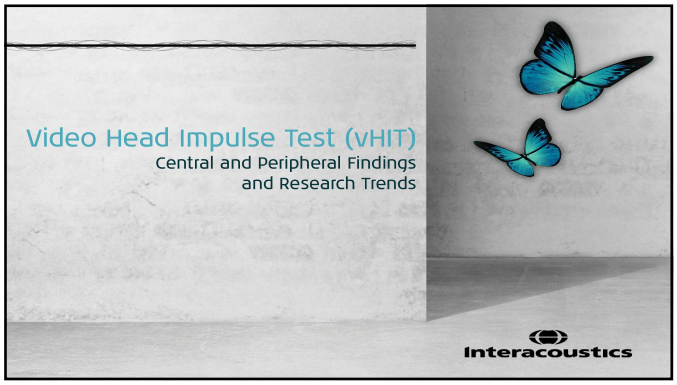


## Video Head Impulse Test (vHIT)

What is vHIT?

- The clinical head impulse/thrust test (cHIT or HTT) method was first reported by Michael Halmagyi and Ian Curthoys in 1988
- They described using manual head thrusts clinically to observe the patient's corrective saccades, indicative of a vestibular loss in the stimulated (as compared to inhibited) horizontal semicircular canal.
- Today, rather than just visual observation, the Video Head Impulse Test (vHIT) provides a graphical record of these saccadic intrusions and a measurement of VOR gain.

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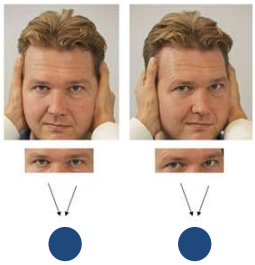
## Normal cHIT/ Normal VOR



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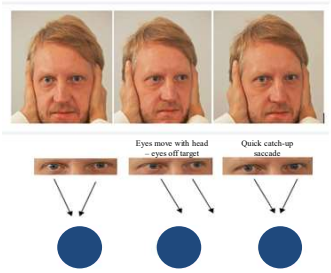
## Abnormal cHIT/ Abnormal VOR

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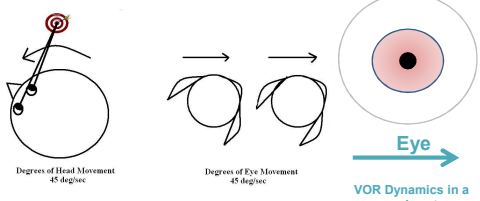
## Traditional Head Thrust Test







VOR Dynamics in a normal system

Halmagyi and Curthoys (1988) head thrust concept

The problem is that these eye movements can happen so quickly that we cannot always see them

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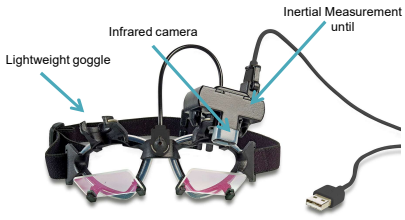
## Video Head Impulse Test

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## Video Head Impulse Test

- Used to asses the condition/functionality of the patient's current state of the Vestibular Ocular Reflexes (VOR).
- Quickly screens for vestibular disorders.
- Provides high frequency vestibular information.
- Provides an asymmetry value to show side differences.
- Reports gain abnormalities and displays corrective saccades.

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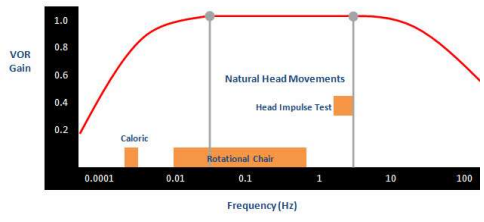
## Video Head Impulse Test

Frequencies Tested:

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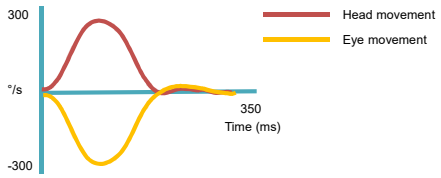
## What Does vHIT Measure?




Head velocity versus eye velocity is measured and displayed

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## What Does it Measure?

- In head impulse testing, there is potential for the patient to generate two types of corrective saccades:
  - Covert – an involuntary saccade that is generated during the head impulse itself (while the head is still in motion)
  - Overt – a more voluntary saccade that is generated after the head has stopped moving (200 ms or later)

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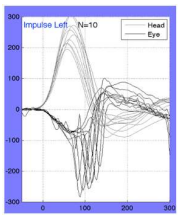
## Corrective Saccades

- vHIT can measure these short duration events at up to 250 samples per second
- Head velocity vs. eye velocity are displayed and gain is measured
- Corrective saccades are strong indicators of a vestibular deficit

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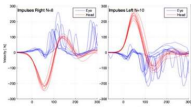
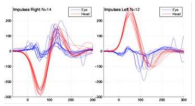
## Corrective Saccades – Generation Sites

What system produces these quick eye movements?



With target present:
- Covert saccades
- Overt saccades



In darkness:
- Covert saccades
- No overt saccades

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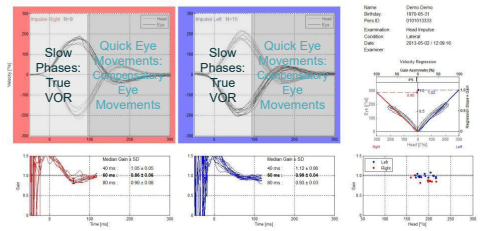
## vHIT looks for slow phase gains and fast phase corrective movements




VNG looks primarily for nystagmus

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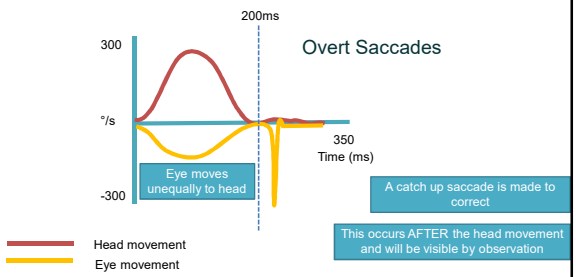
## Corrective Saccades

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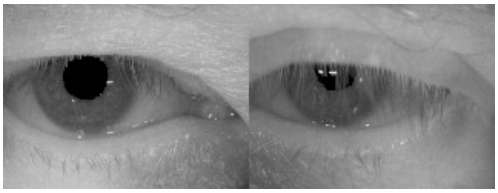
## Corrective Saccades



Overt Saccades

Which side is impaired?

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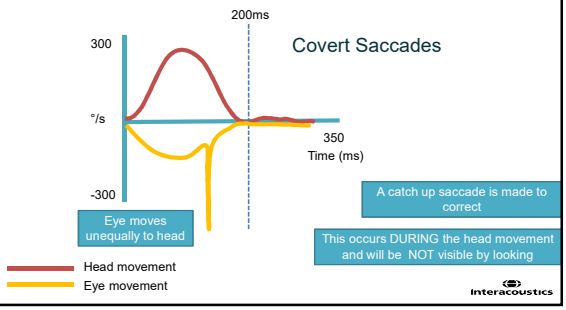
## Corrective Saccades

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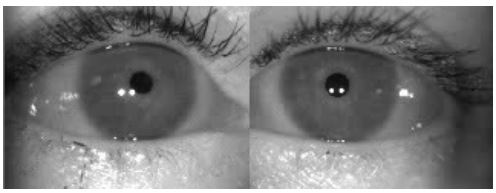
## Corrective Saccades



Covert Saccades

When direct observation fails

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## Corrective Saccades

Overt saccades are visible, but what are we missing?

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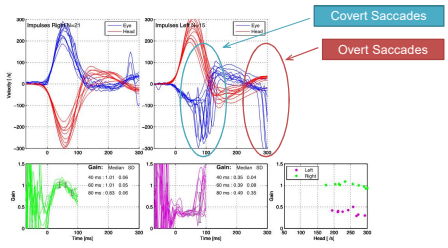
## Corrective Saccades

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## Corrective Saccades

Covert Saccades

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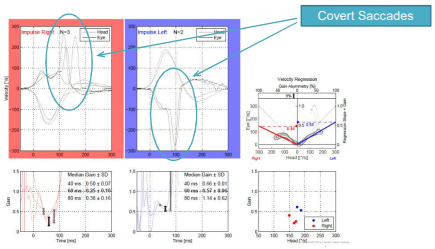
## Corrective Saccades

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## Where Does it Fit into Dizzy Assessment?

- vHIT is often performed bedside or as an initial step in the assessment process.
- The most common findings are in the lateral canal so you can "screen" with lateral impulses, which takes 2 minutes or less, then add in verticals as needed.
- If vHIT is normal, other vestibular function tests will need to be performed, a normal vHIT does not conclude normal vestibular function.
- If your vHIT is abnormal, along with a good questionnaire, you can begin to triage the patients for further workup.

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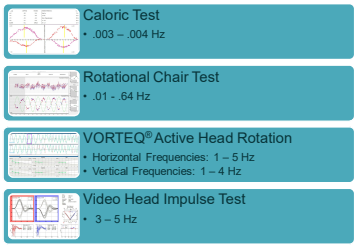
## Where does it fit into my assessment?

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## Where Does it Fit Into My Assessment

- Can be used to determine the presence of a vestibular disorder affecting the semicircular canals
- Can be used to create a baseline measure for vestibular function in progressive disease or degeneration
- Can be used to monitor compensation of a vestibular lesion over time and drive vestibular rehabilitation
- Can be used as a triaging tool to determine whether further investigation is necessary
- May be helpful in differentiating between a stroke and acute vestibular system pathology – Mantokoudis et al, 2014

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## vHIT Test Technique

Producing an effective horizontal head thrust requires:

- Rapid and unpredictable head rotation (in direction and time)
- Small amplitude 10-15° movements
- Peak head velocity 150 °/s +

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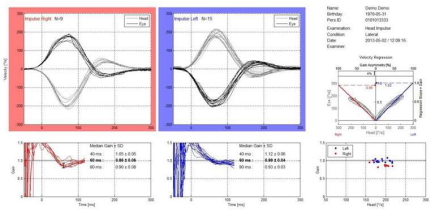
## Normal vHIT Result



Normal Gain = lower cut off 0.76

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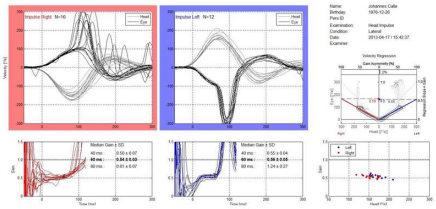
## Abnormal vHIT Result



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## Video Head Impulse Test (vHIT)

only "rapid, . . . unlike slow" head movements demonstrate the VOR gain asymmetry "that is expressed by Ewald's 2nd Law" (Halmagyi et al. 1990)

Abnormal Impulse Recordings

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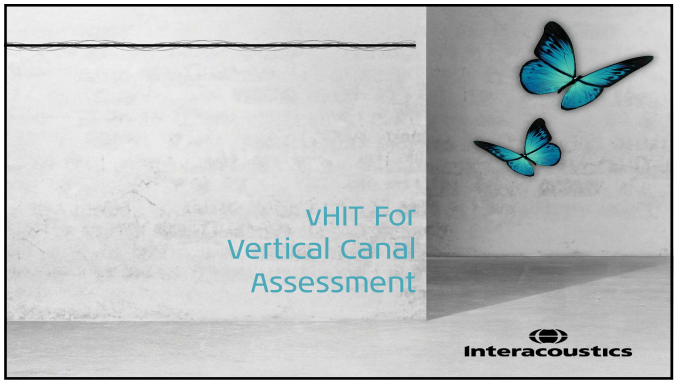
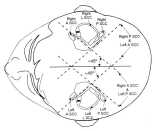
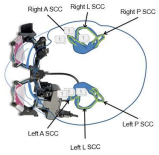


## Assessing All Six Canals

Canals are assessed in pairs:

- Lateral Right and Left
- Left Posterior and Right Anterior (RALP)
- Left Anterior and Right Posterior (LARP)






The caloric test only assesses the horizontal semicircular canal

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## Vertical Impulses - RALP


Right Anterior


Left Posterior


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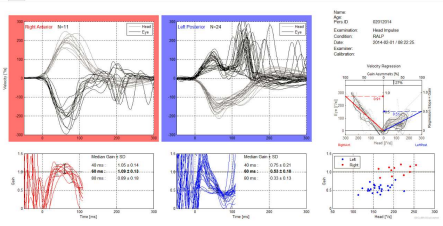
## Vertical Impulses – RALP



Left posterior canal deficit – 27% weaker than right anterior canal

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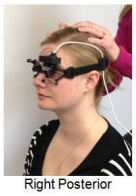
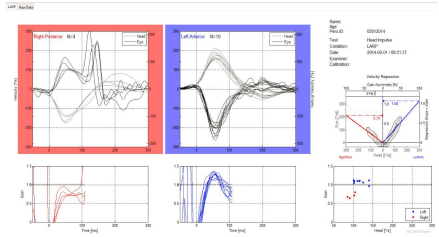
## Vertical Impulses – LARP

Left Anterior



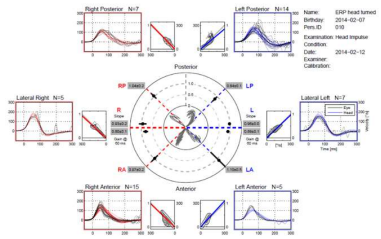
Right Posterior


## Vertical Impulses – LARP



Right posterior canal deficit – 21% weaker than left anterior canal

## EyeSeeSix Final Report



## What about children?

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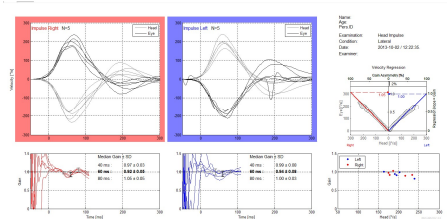
## Results from a 10-month old



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## Peripheral and Central Findings

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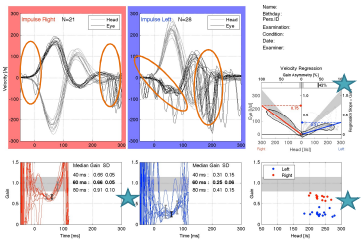
## Peripheral Findings in vHIT – Acute Stage



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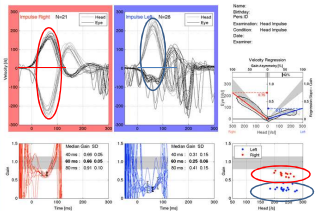
## Peripheral Findings in vHIT

Low Gain on Contralesional Side:

- During contralesional impulses (towards the healthy side), UVL patients may generate deficient VOR slow-phases
- The healthy contralesional side is initially compensating for the loss



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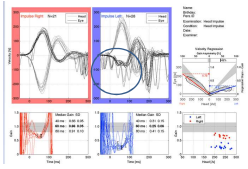
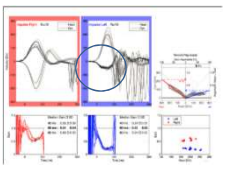
## What's Happening?

Friday 9 45 pm



Saturday 8 00 am



Less spontaneous nystagmus

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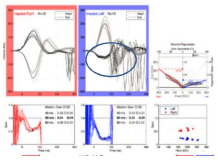
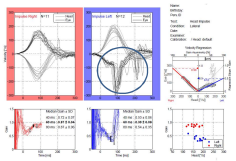
## What's Happening?

Saturday 8 00 am



1 week after Physical Therapy



PT Protocol Gaze Stabilization exercises, VOR strengthening exercises

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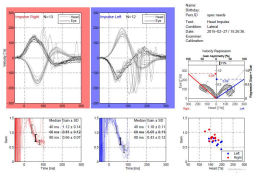
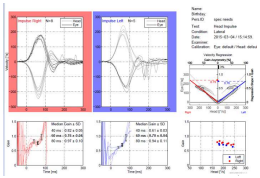
## Peripheral Findings in vHIT

Another example of compensation



Pre-Physical Therapy



Post-Physical Therapy

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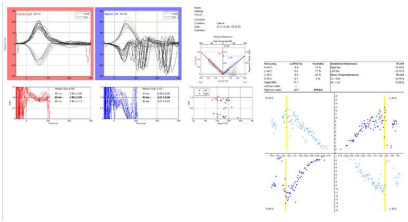
## vHIT Peripheral Findings – Chronic Lesions

Some Vestibular Neuritis patients do not completely recover.



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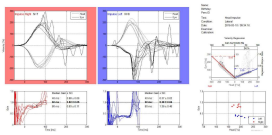
## Peripheral Findings in vHIT – Summary

- Spontaneous Nystagmus may be evident in vHIT tracings in acute stage
- Not uncommon to see small effects on the contralesional side, initially
- vHIT may be able to show signs of compensation in some peripheral cases



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## Central Findings in VHIT

Saccades in the "wrong" direction?

High gain with no indications of noise, slippage or other artifact

- "Backup saccades"
- "Reversed saccades"
- "Anti-saccades"
- "Covert anti-compensatory saccades (C - AQEM)"
- "Stop Phenomena"

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## Backup Saccades?

"Back-up saccades are almost always a central sign, suggesting brain disease rather than ear disease".

The reason is that the VOR gain is tightly controlled by the brain. Should one's VOR gain be too high, the brain would rapidly suppress it. Thus, back-up saccades should mean that there is a cerebellar disturbance.

Dr. Hain, Chicago Dizzy and Balance
www.dizziness-and-balance.com/testing/ENG/vhit.html

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## Central Findings in vHIT

Reversed Corrective Saccades during Head Impulse Test in Acute Cerebellar Dysfunction (Choi et al, 2014)

- Cerebellar findings (spontaneous downbeat, flutter, dysmetria…)
- Autoimmune related?
- Acute Cerebellitis – may result in abnormally increased VOR responses due to cerebellar disinhibition over the VOR

Choi JY, Kim JS, Jung JM, Kwon DY, Park MH, Kim C, Choi J. Reversed Corrective Saccades During Head Impulse Test in Acute Cerebellar Dysfunction. The Cerebellum. 2014;13(2):243-247

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## Cerebellar Disorders

- HIT is mostly normal
- Present horizontal or downward catch-up saccades are common
- Increased gain of VOR
- Reversed corrective saccades cannot be seen in bHIT, but can be detected with vHIT

Choi et al, 2014 – published 2 cases

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## Lateral vHIT with Downward Saccades

Borrowed from Leonel Luis, M.D.

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## Detecting Backup Saccades

- Check the velocity profile for spikes of eye velocity that occur during the head thrust, and that present in the opposite direction as the VOR.
- This observation is potentially very important. Small "backup" saccades are still saccades - -they are very fast.
- The vHIT device can detect and record tiny backup saccades that one cannot observe with the naked eye.
- Finding "backup" covert saccades is a unique capability of the vHIT, they cannot be identified by either the VNG or Rotatory Chair tests (due to slower camera speeds and lower frequencies of the VOR).

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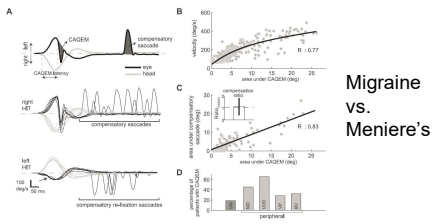
## Covert Anti-Compensatory Quick Eye Movements during Head Impulses

Maria Heuberger[1,2,*], Murat Sağlam[1,*], Nicholas S. Todd[1], Klaus Jahn[1,2], Erich Schneider[1,3,4], Nadine Lehnen[1,2]

1 German Center for Vertigo and Balance Disorders, Munich University Hospital, Munich, Germany, 2 Department of Neurology, Munich University Hospital, Munich, Germany, 3 Institute for Clinical Neurosciences, Munich University Hospital, Munich, Germany, 4 Brandenburg Institute of Technology, Cottbus - Senftenberg, Germany



Migraine
vs.
Meniere's

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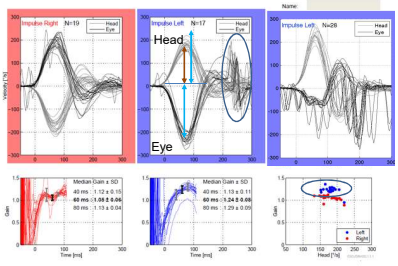
## Vestibular Migraine

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## Compensatory Saccades

These saccades occur in patients with a supra-normal VOR, in which case they are indeed compensatory.

They bring the eyes back to target in case there is a VOR overshoot.

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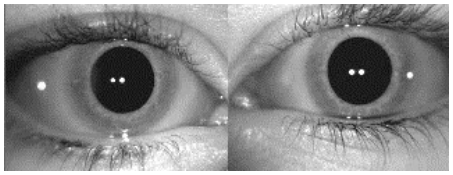
## Patient with Multiple Conditions

Diagnosed with Migraine associated vertigo, psoriasis and Graves' Disease (Hyper-Thyroid).

Autoimmune disorders……..



Right-beat and down-beat

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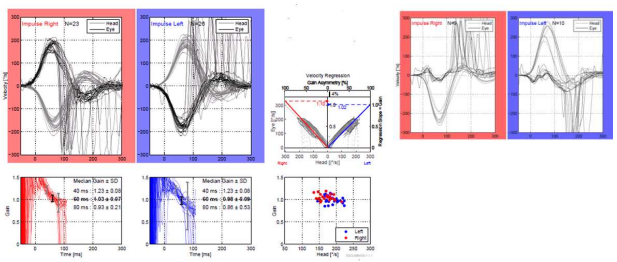
## Patient with Multiple Conditions



- Audio, MRI, ECOG, VNG, and VEMPs were all normal
- vHIT revealed saccades

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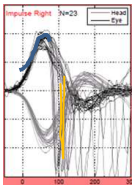
## Non-Compensatory Saccades?

- The saccades or quick eye movements are in the opposite direction of the VOR slow phase, just as in the case of "compensatory back-up" saccades,
- But in this case they are not compensatory……..
- They do not fulfill the purpose of bringing the eye back to target. Instead, the eye is directed even further away into the direction of the head movement, just as with nystagmus quick phases.

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## Patient with Ramsay Hunt Syndrome

Ramsay Hunt syndrome (herpes zoster oticus) occurs when a shingles infection affects the facial nerve near one of your ears. In addition to the painful shingles rash, Ramsay Hunt syndrome can cause facial paralysis and hearing loss in the affected ear.

Symptoms may include:

- Ear pain
- Hearing loss
- Ringing in your ears (tinnitus)
- Difficulty closing one eye
- A sensation of spinning or moving (vertigo)
- A change in taste perception or loss of taste

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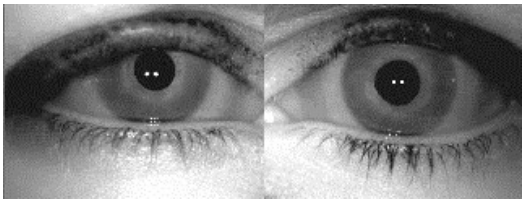
## Patient with Ramsay Hunt Syndrome



Square-wave jerks present during the VNG oculomotor test battery

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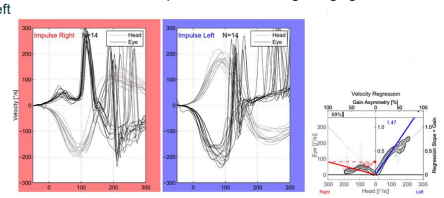
## Patient with Ramsay Hunt Syndrome

- Mild sensorineural hearing loss
- Normal VNG, normal rotary chair results
- Low gain with covert and overt catch-up saccades on the right, high gain and backup saccades left

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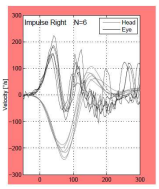
## Central Findings in vHIT – Summary

- Migraine, Ménière's and Cerebellar Disorders often have normal vHITs, but in some cases we see abnormally high gains with "reverse" saccades.
- We need to pay attention to backup or "anti-saccades"
- Backup covert saccades are unique to vHIT testing
- More studies are needed before we can better understand these phenomena

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## vHIT Advantages

- Objective measure of vestibular function
- Low variability in test findings
- Assesses each peripheral vestibular system independently
- Can assess all six semicircular canals
- Uses a more natural stimulus for better estimate of function
- No tasking needed and less affected by meds than calorics
- Can be used on a broad population
- Very quick to perform
- Generally well tolerated by patients

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## Utilizing vHIT for SHIMP

- In suppression head impulse paradigm (SHIMP) the patient focuses on a head-fixed target, instead of an earth-fixed target
- vHIT goggle is placed on the patient in the same way
- Test is performed on lateral canals
- During head thrusts, the patient follows the calibration light projected from the goggle with their eyes
- Anti-compensatory saccades in SHIMP indicate that the patient has vestibular function (corrective saccades in vHIT indicate vestibular dysfunction

MacDougal et al, 2016

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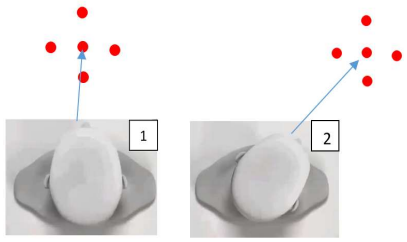
## Utilizing vHIT for SHIMP

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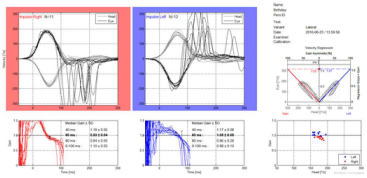
## Utilizing vHIT for SHIMP

A patient with normal vestibular function should have SHIMP results that appear similar to this



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## Utilizing vHIT for SHIMP

- Conventional head impulse test is used clinicially to identify a deficit in the VOR
- SHIMP testing is used clinically to identify vestibular function
- Subjects with a normal VOR must make corrective saccades to follow a head-fixed target
- The two tests provide complementary results
- SHIMP can be useful in understanding the level of residual function to help a patient with realistic expectations before beginning vestibular rehabilitation

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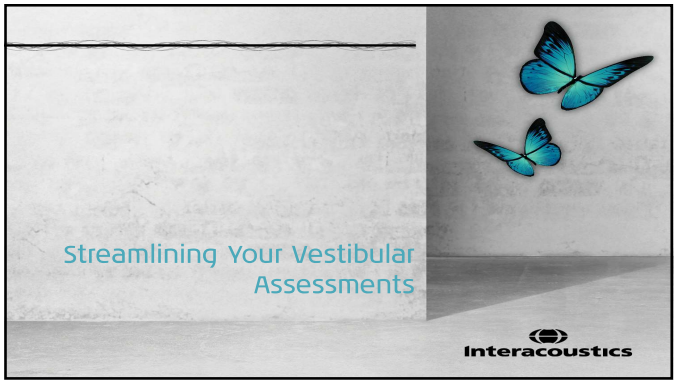

## Streamlining Your VNG Evals

Tips for Oculomotors:

- Smooth pursuit frequencies to test
- Smooth pursuit – how many cycles?
- Always look for best performance
- Saccades – how many are enough?
- Gaze angles and test time (monitor size does matter)
- OPK speed(s) and stimuli
- When to edit results
- Don't over-interpret

Hamid A. (2006): Medical Otology and Neurology: A Clinical Guide to Auditory and Vestibular Disorders. Theime, New York, NY.

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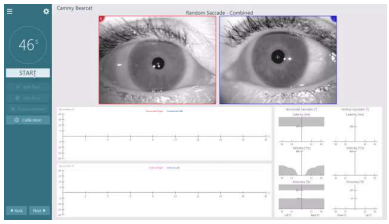
## Streamlining Your VNG Evals

Saccades – how many are enough?



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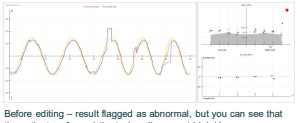
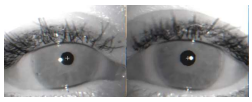
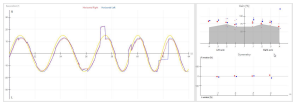
## Streamlining Your VNG Evals

Smooth Pursuit:



Before editing – result flagged as abnormal, but you can see that the patient performed the task well, even at high Hz





After editing – result in normal

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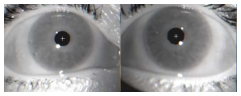
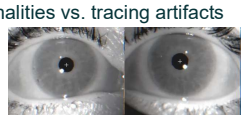
## Streamlining Your VNG Evals

Gaze:

- When possible based on stimulus device, test at 30° horizontally and 20° vertically
- 10 seconds each direction is typically plenty, add time as needed when abnormalities are present
- Watch videos for true abnormalities vs. tracing artifacts



Gaze right with right-beating nystagmus



Gaze left with left-beating

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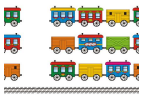
## Streamlining Your VNG Evals

OPK:

- Use a stimulus that will produce a good reflexive OPK response
- Don't over-instruct the patient
- If only testing at one velocity, use higher velocity



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## Streamlining Your VNG Evals

Tips for Positionals/Dix-Hallpikes:

- Which positions to test
- How long to test
- When should fixation in positionals be used?
- When to edit results
- Requirements for billing

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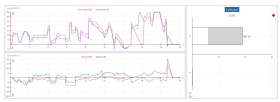
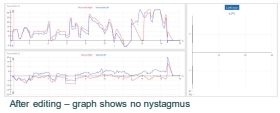
## Streamlining Your VNG Evals

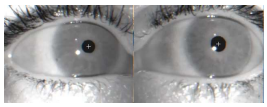
Editing Positionals/Dix-Hallpikes:



Before editing – looks like 19 deg/sec RB



After editing – graph shows no nystagmus



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## Streamlining Your VNG Evals

Tips for Calorics:

- MWST considerations
- Time to wait between calorics
- Using caloric wait-time usefully
- When to edit results – differences between m.SPV vs. a.SPV

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## Streamlining Your VNG Evals

MWST Considerations:

- Several studies have looked at monothermal caloric testing and many researchers believe that it is a good screening tool when warms are used – Monothermal Warm Screening Test (MWST)
- There is a significant positive correlation between bithermal and monothermal warm unilateral weakness
- In a review of 15 monothermal studies, the sensitivity ranged from 54%-100% and specificity ranged from 25% to 96%

Adams ME, Telian SA, Kane RL, Butler M. Monothermal caloric screening test accuracy: A systematic review. Otolaryngology-Head and Neck Surgery. 2016; 15(6): 982-996.

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## Streamlining Your VNG Evals

MWST Considerations:

- Since it can really only be used as a screening tool and not a diagnostic tool, the following criteria should be employed:
  - If the percent difference between sides exceeds a critical value (15%), then MWST should be considered abnormal and must proceed with cool irrigations
  - MWST should only be employed if there are no other abnormalities identified in the VNG up to that point (no oculomotor abnormalities, no significant spontaneous or positional nystagmus)
  - SPV of both warm irrigations must exceed 11°/sec

Lightfoot G, Barker F, Belcher K, Kennedy V, Nassar G, Tweedy F. The derivation of optimum criteria for use in the monothermal caloric screening test. Ear Hear. 2009; 30(1): 54-62.

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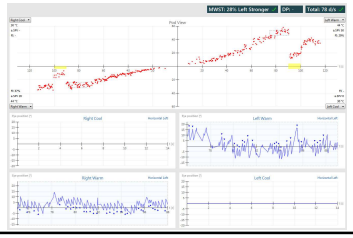
## Streamlining Your VNG Evals

MWST Calculation: $\frac{LW-RW}{LW+RW} \times 100 = \%$



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## Streamlining Your VNG Evals

Editing Calorics:

- When using an a.SPV method for identifying peak response, editing is much less of an issue than when using m.SPV
- Watch tracings for things like excessive eye blinks and artifact that could be picked up by the software as nystagmus – remove outliers as needed, but don't be concerned with too much cleaning up
- Keep watching eyes to ensure that the crosshairs are staying locked in on patient pupils throughout the caloric test
- Remind the patient throughout the test to look up towards his forehead – this will keep lashes out of the way so you get better tracking and cleaner traces

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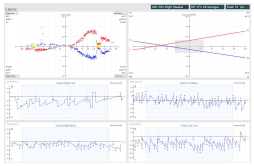
## Streamlining Your VNG Evals

Editing Calorics:

- Watch pods for outliers
- Make sure that the numerical values (UW, DP) make sense based on the nystagmus you see in the tracings



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## Streamlining Your VNG Evals

Editing Calorics:


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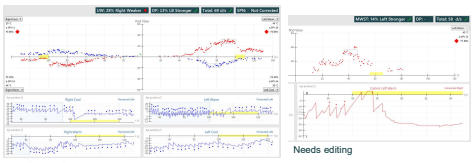
## Streamlining Your VNG Evals

Editing Calorics:

- Watch the fixation section for artifact that might be creating a positive fixation index that is not really due to failure fixation suppression – always crosscheck with the other caloric and SP



Real fixation failure



Needs editing

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## Streamlining Your VNG Evals

Maximizing VNG Protocols:

- Create two or three protocols that meet needs for various scenarios
  - Basic VNG (92540 and 92537)
  - Extended VNG
  - Spontaneous and Hallpikes (92541, 92542)
- Decide on set protocols that all clinicians can agree upon
- Start with the basics
- Save advanced protocols for cases where really needed

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## Streamlining Your VNG Evals

Suggested Basic Oculomotor Protocol:

- Spontaneous Test – 20 seconds fixation-free, 15 seconds with fixation
- Gaze Test – 10 seconds in each gaze position (with fixation)
- Smooth Pursuit – 2-3 cycles at 0.1 Hz, 0.2 Hz, 0.4 Hz
- Saccades – 20-30 saccades if doing horizontal only, 40 if doing a combined horizontal/vertical test
- OPK – start with higher velocity (40°/s)

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## Streamlining Your VNG Evals

Suggested Basic Positional/Positioning Caloric Protocol:

- Dix-Hallpikes – 30 seconds each side, add time as needed when abnormal or suspected abnormal
- Positionals – 30 second fixation-free in each position (supine, head right, head left)
- If abnormal, add side right, side left
- If abnormal, turn on fixation for each position in which nystagmus was observed
- Calorics – start with warms

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## Streamlining Your VNG Evals

One last suggestion for VNG evals:

- Keep a make-up tool kit available
- It will save you time – don't spend your time trying to get clean and reliable results when conditions are not ideal (eye make-up, light leakage, etc.)
- Last resort – switch to electrodes

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## Streamlining Your vHIT Evals

vHIT Protocol Recommendations:

- Start with laterals – in a study looking at 703 vestibular neuritis cases, only 9 were diagnosed with inferior vestibular neuritis

Kim JS, Kim HJ. Inferior vestibular neuritis. J Neurol. 2012; 259(8): 1553-1560.

- 7-10 impulses with clean traces in each direction is usually plenty – just need enough to establish a pattern
- Add verticals as needed – when laterals are normal or when additional information is needed

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## Streamlining Your vHIT Evals

Technique Tips:

- Make sure the strap is very secure on the patient's head
- Keep the impulse amplitude very small (10-15° is plenty)
- High velocity is required (150-300°/sec)
- At the end of an impulse, keep the patient's head still (do not move the head back to the start position immediately)
- Avoid touching the goggles, strap, USB cord during impulses
- Make sure pupil stays in viewing area during impulses
- Should you impulse outward or inward? (Magnusson, 2015)

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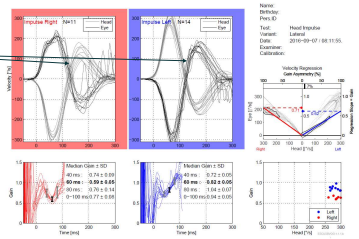
## Streamlining Your vHIT Evals

Common Artifacts Related to Technique:

Rebound after impulse



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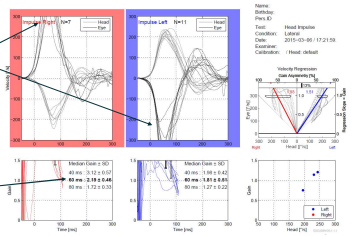
## Streamlining Your vHIT Evals

Common Artifacts Related to Technique:

Slippage

Result = high gain



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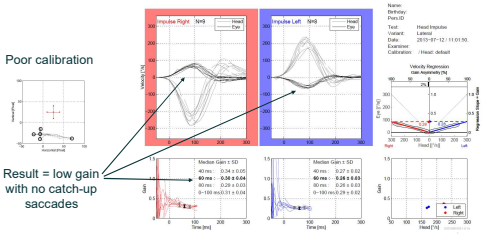
## Streamlining Your vHIT Evals

Common Artifacts:

Poor calibration

Result = low gain with no catch-up saccades



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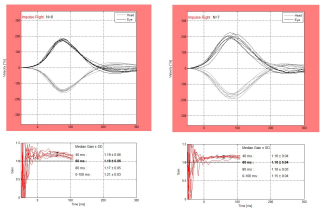
## Streamlining Your vHIT Evals

vHIT Outward Impulses vs. Inward Impulses:

Gain differences between outward and inward thrusts is very slight – both methods acceptable for clinical use



Outward Impulses | Inward Impulses

Nyström A, Tjernström F, Magnusson M. Outward versus inward head thrusts with vHIT testing in normal subjects: Does it matter? Otol Neurotol. 2015; 36: e87-e94.

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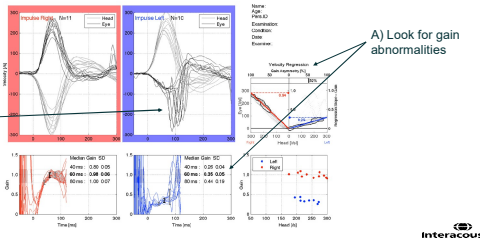
## Streamlining Your vHIT Evals

Identifying Abnormalities:

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## Streamlining Your VEMP Evals

oVEMP and cVEMP Protocol Recommendations:

- Prepare electrodes for both tests
- Start with cVEMP
- Perform high intensity recording on each side (i.e. 97 dB)
- Decrease intensity (70 dB) to screen for superior semicircular canal dehiscence (SSCD)
- Threshold search as needed
- Switch to oVEMP and perform high intensity recordings on each side
- Increase frequency as needed to rule out Ménière's and SSCD

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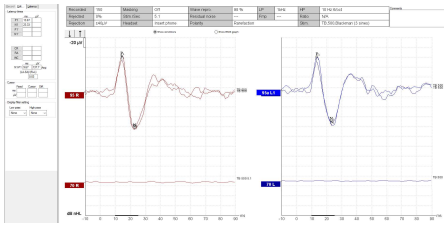
## Streamlining Your VEMP Evals

cVEMP Protocol:



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## Questions?

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## Thank You

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