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Overcoming Barriers to Video Head Impulse Testing in the Pediatric Population, presented in partnership with Cincinnati Children's

Presenter: Violette Lavender, AuD
Micheal Castiglione, AuD

Moderator: Carolyn Smaka, AuD, Editor in Chief, AudiologyOnline

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Overcoming Barriers to Video Head Impulse Testing (vHIT) in the Pediatric Population

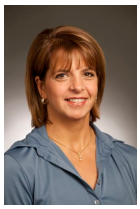
Violette Lavender, AuD
Micheal Castiglione, AuD

AudiologyOnline

Cincinnati Children's

Our Team

John Greinwald, MD



Katheryn Bachmann, PhD

Violette Lavender, AuD

Gretchen Mueller, DPT

Daniel Choo, MD

Crystal Manninen, AuD

Micheal Castiglione, AuD

Kim Yungbluth, DPT

Ashley Cabrera, DPT

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Objectives

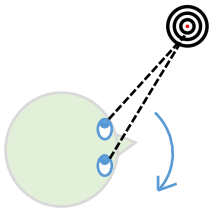
- The learner will be able to describe 3 modifications for ensuring good goggle fit and seat positioning of the child during vHIT testing.
- The learner will be able to identify 2 pediatric focused visual targets for vHIT testing.
- The learner will be able to identify at least two possible abnormal outcomes from vHIT testing and what they might imply clinically.

What is vHIT

- Developed by Halmagyi and Curthoys in 1988
- Looks at the ability of the eye to maintain focus on a target during head movement
- Simulates head movements required for ADLs

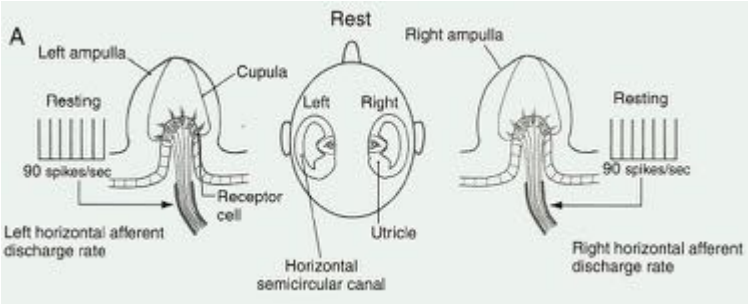
Vestibulo-Ocular Reflex (VOR)

- The VOR allows for *stable gaze* (focused clear vision) while the head is moving by generating *eye movements that are equal and opposite to head movement*



HIT Physiology

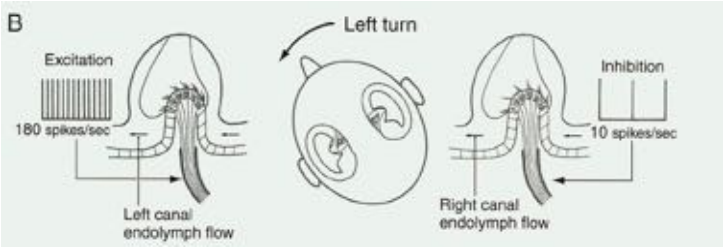
- When the head is at rest
  - Both labyrinths are constantly discharging signals to the brain



HIT Physiology

When the head is turned

- The SCC the head is turned toward ↑ its discharge rate
- The SCC away from the head turn ↓ its discharge rate



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Head Impulse Testing

- With unilateral and bilateral vestibular system impairments
  - abnormal "catch-up" (refixation) saccade when the head is thrust in the direction of the impaired SCC
- Studies have shown that catch up saccades can be seen best by the human eye if the caloric weakness is 42.5% or greater.

Perez and Rama-Lopez 2003

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Overt/Covert Saccades

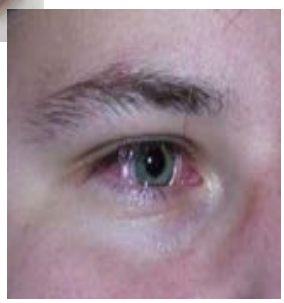
- Overt Saccade: Rapid eye movement made to bring the eye back to the focal point *after* the head movement has stopped (~100 msec after)
- Covert Saccade: Rapid eye movements occurring *during* the head movement in order to keep the eye on the focal point (cannot be seen with the naked eye)

What does vHIT test

- Measures the VOR gain of all 6 semicircular canals
- Determine the presence of overt and/or covert saccades

HIT with the Scleral Search Coil

(Robinson, 1963)



But Yikes!

- Coil adhered to eye with contact-like ring
- Coil created magnetic field
- Magnets placed around eye
- Could detect very small eye movements (< 1 deg)
- Great temporal resolution (< 1msec)
- Sensitivity and Specificity of 1.0

vHIT vs. Search Coil

Findings:

1. Gain of the vHIT and search coils was not significantly different.
2. With a sensitivity and specificity of 1.0!
3. Validated for clinical use

H.G. MacDougall, K.P. Weber, L.A., McGarvie, G.M. Halmagyi, and L.S.Curthoys , *Neurology*, 2009 Oct 6;73(14):1134-41.

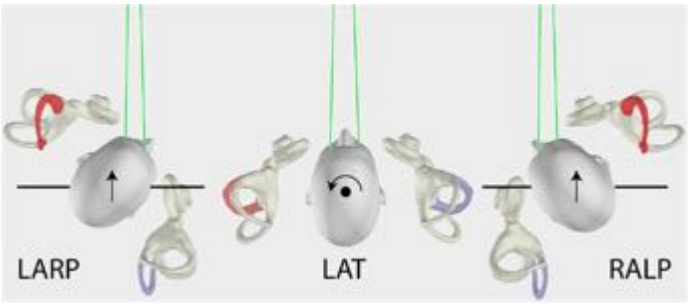
vHIT

- High speed video (frame rate > 200Hz)
- Light weight goggles (minimize slippage)
- Maintain the sensitivity of the scleral search coil

vHIT: How to….

- **Subject Position** – seated at least 1 meter from a 1”x 1” focal sticker on a wall
- **Calibration (in vivo)-** to measure pupil displacement
  - 2 laser dots 15 deg apart on either side of the focal sticker
- **Instructions to patient -** “I am going to be turning your head in different directions. I need you to relax your neck and just keep staring at the sticker on the wall”.

vHIT: How to….



vHIT: How to…. Lateral

- Video 1 Lateral

vHIT: How to…. RALP

- Video 2 RALP

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vHIT How to…. LARP

- Add Video 3 LARP

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vHIT: Response Parameters

1) Gain: The relation between head movements and eye movements during a head thrust - characterized in velocity. E/H = GAIN

2) Overt Saccade: Rapid eye movement made to bring the eye back to the focal point *after* the head movement has stopped (~100 msec after)

3) Covert Saccade: Rapid eye movements occurring *during* the head movement in order to keep the eye on the focal point (cannot be seen with the naked eye)

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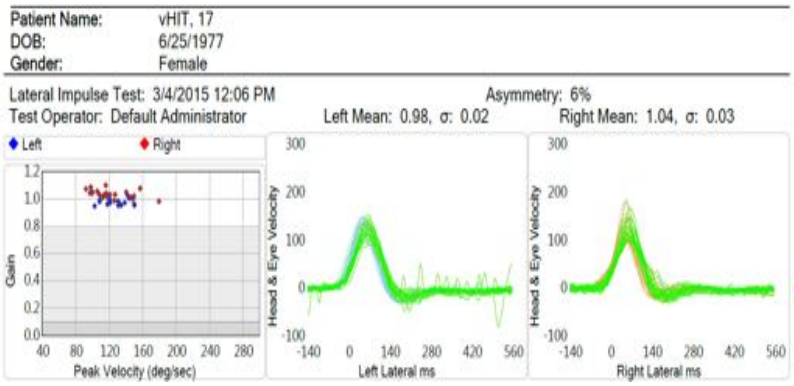
vHIT Interpretation: Normal LSCCs



Normal gain for adults: Mean: 0.96 Range 0.79 – 1.20

Curthoys, MacDougall, et al. (2016) – Sydney Clinic Norms

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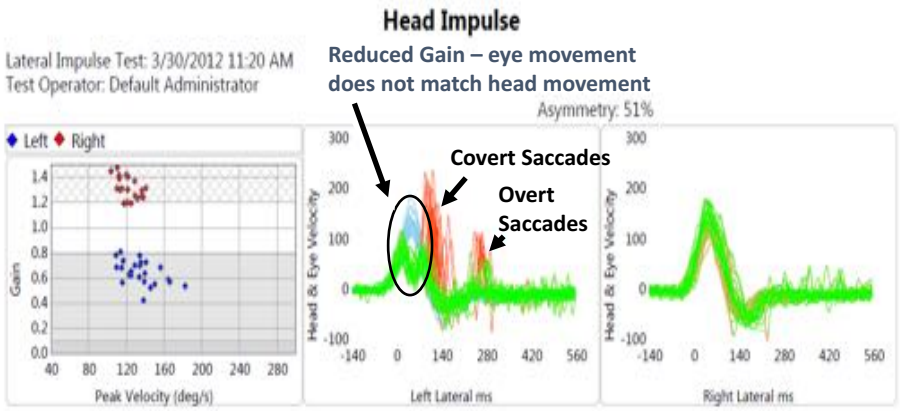
vHIT Interpretation: Unilateral Loss



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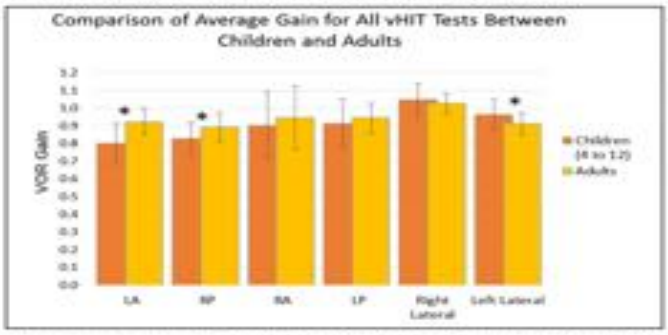
vHIT Interpretation

- Reduced gain on its own is not sufficient evidence of an abnormal canal response. Should see catch up saccades, too.
- Catch up saccades are identified by *direction*, *timing*, *velocity* & *consistency*
  - **Direction:** Abnormal catch up saccades occur in the ***SAME*** direction as the VOR (if seen in opposite direction – this is usually spontaneous nystagmus)
  - **Timing:** 1st catch up saccade occurs w/in ~70-270 msec after the onset of head movement
  - **Velocity:** Catch up saccades that are substantially smaller than the peak head velocity are not abnormal. Saccade needs to be bigger than ½ the head velocity
  - **Consistency:** Abnormal catch up saccades occur for almost every head impulse toward the side of lesion

AudiologyOnline 26 ICSimpulse.com (2015) Cincinnati Children's

Normative data: CCHMC, in review

Comparisons of the pediatric and adult VOR gain measures revealed a statistical significance ($p < 0.05$) for the LA, RP, and left lateral vHIT tests.



Average gain comparisons between adults (n=11) and children 4-12 years (n=30) for all vHIT tests. LA= Left Anterior; RP= Right Posterior; RA= Right Anterior; LP= Left Posterior. *p< 0.05

Normative Data

- Average VOR gains for healthy subjects across studies of adults and children

SCC	LA	RP	RA	LP	Right Lateral	Left Lateral
Children (Bachmann et al., 2015)	0.80 ± 0.11 (0.58 - 1.02)	0.83 ± 0.09 (0.65 - 1.01)	0.90 ± 0.19 (0.53 - 1.28)	0.91 ± 0.14 (0.65 - 1.19)	1.04 ± 0.09 (0.87 - 1.22)	0.96 ± 0.09 (0.79 - 1.14)
Adults (Kidd et al., 2014)					1.04 ± 0.11 (0.82 - 1.26)	0.98 ± 0.10 (0.78 - 1.18)
Adults (Curthoys et al., 2016)	0.96 ± 0.12 (0.71 - 1.20)	0.98 ± 0.15 (0.68 - 1.28)	0.95 ± 0.12 (0.70 - 1.19)	0.92 ± 0.17 (0.58 - 1.26)	1.00 ± 0.07 (0.86 - 1.14)	0.92 ± 0.06 (0.80 - 1.04)

Normative Data

- Test time comparison

Test Time

Age Group (years)	Lateral	LARP	RALP
4-6	2:00 ± 0:46	3:23 ± 2:18	2:47 ± 1:40
7-9	1:32 ± 0:22	2:01 ± 0:47	1:32 ± 0:40
10-12	1:18 ± 0:21	2:02 ± 1:27	1:40 ± 0:43
Adults	1:24 ± 0:30	1:49 ± 1:00	1:26 ± 0:46

Mean ±SD test time for each vHIT test by age group.

Normative Data

- Conclusions
  - VOR gains for children are not different from adults for Lateral Impulses and testing in the RALP plane
  - VOR gains are lower in children for LARP testing
  - There is more variability in VOR gains for anterior canal testing (RA & LA)
    - Most likely due to larger pupil size in the pediatric population compared to adults
    - Pupil more likely to be obscured by the eyelid during impulses for RA & LA

Challenges and Solutions

Positioning: Challenges

- Stabilizing
  - Feet do not touch the ground, fidgety, head in motion, risk moving their whole body if not stable during an impulse
- Comfort
  - Motivation to continue testing is tied to patient comfort, not wanting to sit on chair independently

Positioning: Solution
Adjustable Chair with Food Support

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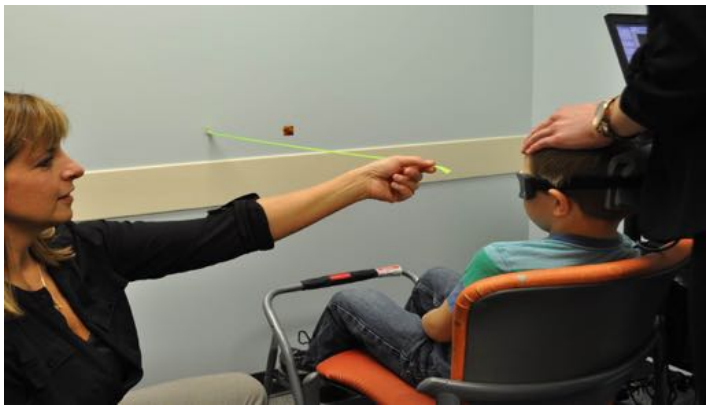
Positioning: Solution
Use of Footstool



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Positioning: Solution
Sitting on Parent's Lap

Video 4 Parent's Lap

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Positioning: Solution
Criss-cross applesauce

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Goggle Placement: Challenges

- Difficulty tolerating goggles
- Retention
- Pupil size and eyelid interference

Goggle Placement: Solution
Instructions

- Video 5 Goggle Instructions

Goggle Placement: Solution
Retention

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Goggle Placement: Solution
Retention

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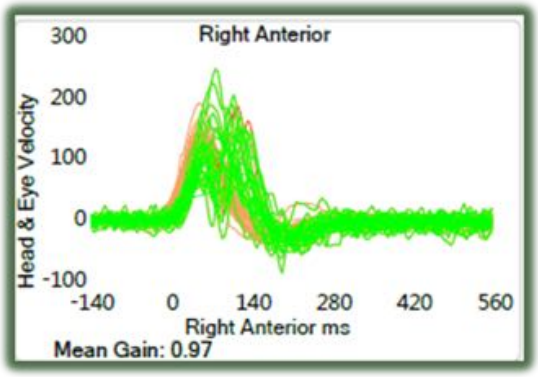
Goggle Placement: Solution
Eye Technique

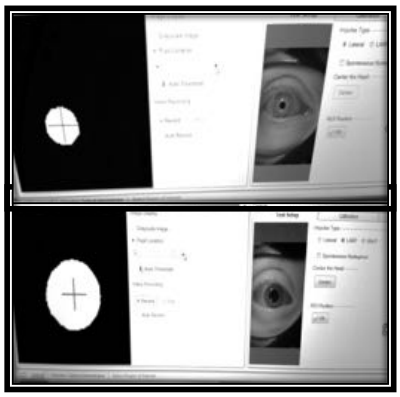
- Video 6 Eye Technique

Eyelid Artifact



Pupil Size: Adult vs. Child

Difference in pupil diameter between a 47 y.o. subject (top) and a 10 y.o. subject (bottom)



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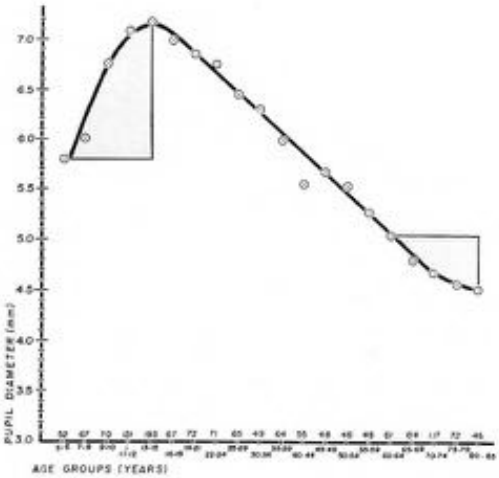
Pupil Size



Jacobson (2002)

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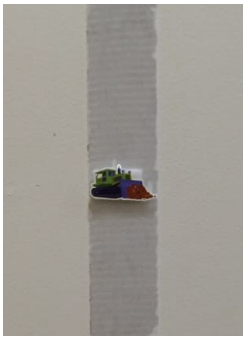
Attention/Motivation: Challenges

- Difficulty maintaining focus on target
- Easily bored

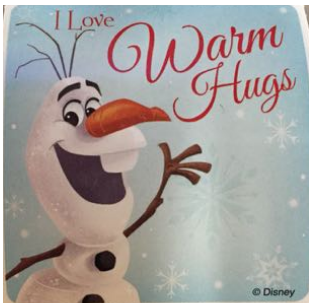
Attention/Motivation: Solution
Child Friendly Stickers

- Use a variety of stickers
- Ask the child questions about the sticker



Attention/Motivation: Solution

- Character Sticker 2 X 2



Attention/Motivation: Solution
Video

- vHITvideo

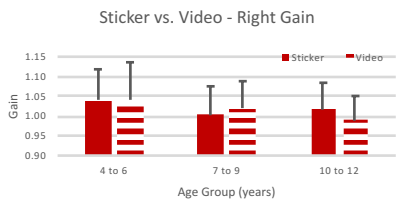
vHIT Video Study

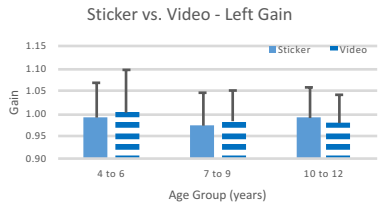
- Research to compare use of video vs. sticker
- 1 inch sticker vs 4 inch video
- Stationary target vs moving target

vHIT Video Study

- Data Points:
  - Effect on gain
  - Time study
  - Asymmetry
  - Saccades generated from video?

Video Study Findings: Lateral Canal Gain





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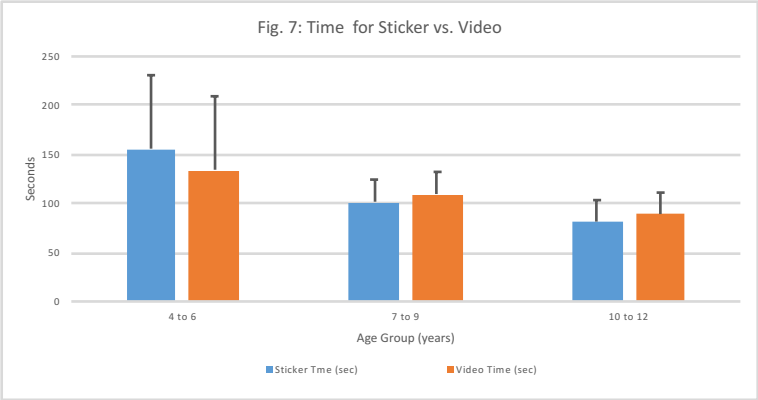
Video Study Findings: Time for sticker vs. video Testing



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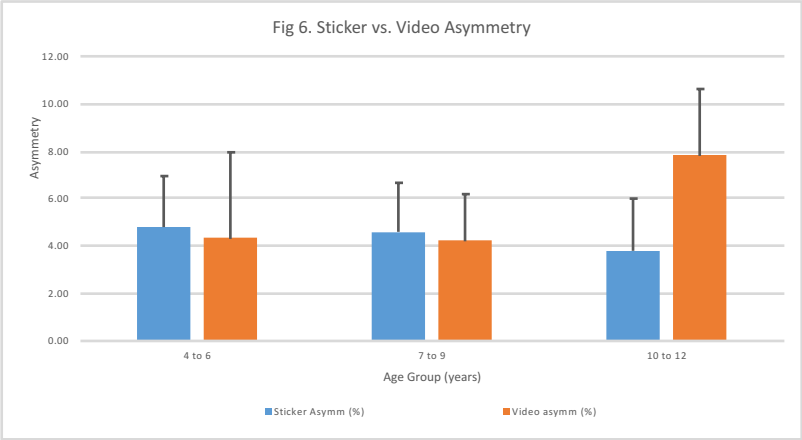
Video Study Findings: Asymmetry



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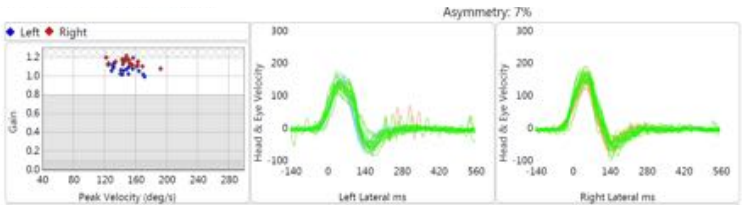
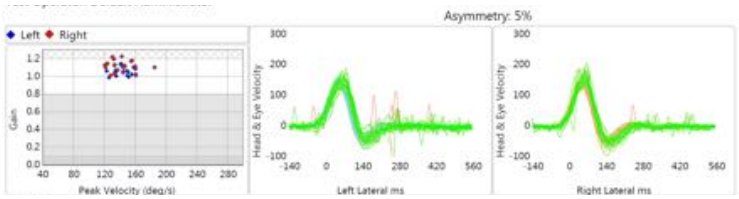
Video/Sticker comparison

- Sticker



- Video



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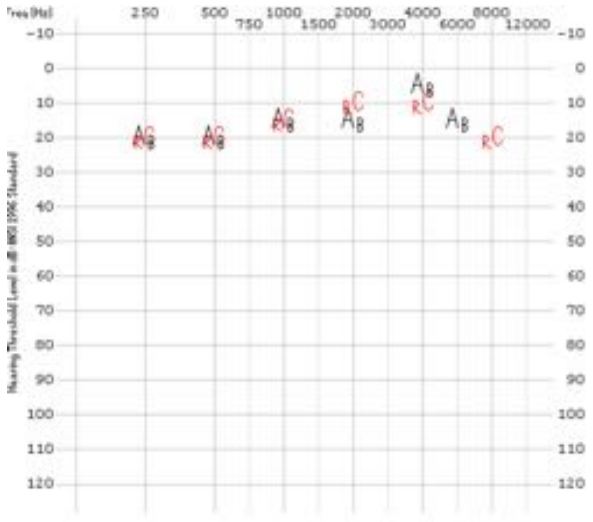
Case Studies

Case Study 1: History

- SNHL bilaterally
- Bimodal user (HA left/CI right)
- Dizziness since age 5 (prior to implantation)
- Increase in intensity and frequency over past 6 months
- Recent decrease in hearing as well
- CMV cannot be ruled out
- Symptoms described as “I fall to the floor”, “everything is spinning” and “I feel sick to my stomach”
- Head movements (looking up and down) can bring on an episode
- Previously received vestibular rehab-did well and discontinued services-episodes returned
- Treated multiple times for BPPV with no relief



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Case Study 1: Test Results

- Rotary-SHA low gain in low frequencies, clockwise asymmetry and phase leads at all test frequencies
- No post headshaking or positional nystagmus
- Dix-Hallpike with vision not occluded was normal. Rotary and up beating noted in the head right position with vision occluded
- Normal cVEMPs and Calorics
- Abnormal DVA screening
- vHIT results ???

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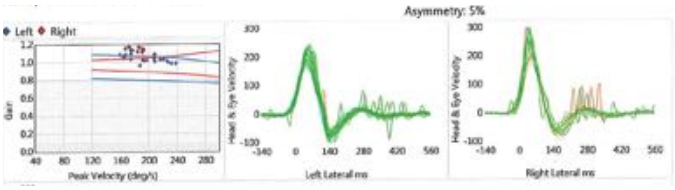
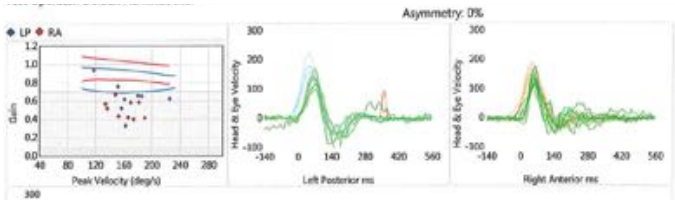
Case Study 1: vHIT Findings

Horizontal

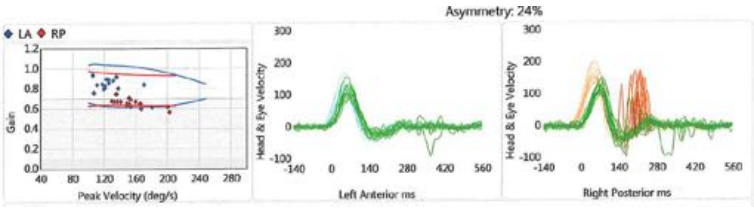


RALP



Case Study 1: vHIT Findings

LARP



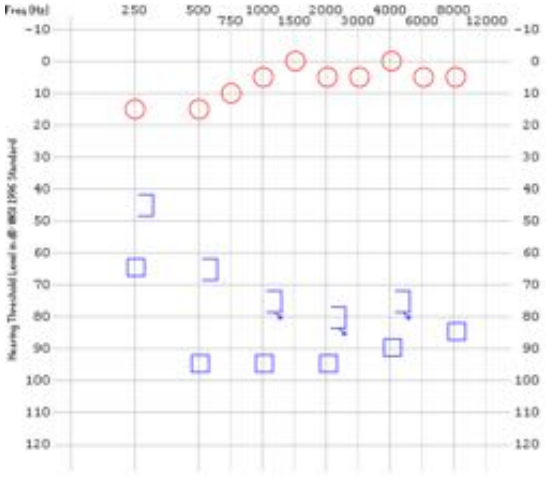
Case Study 1

- Follow-up for vestibular rehab for habituation exercises.

Case Study 2

- 9 year old female
- balance and falls since toddlerhood
- falls have become more evident as she gets older -involved in more activities i.e. gymnastics.
- Falls are random, some days worse than others
- takes stairs one at a time rather than alternating her feet.
- learned to ride a bicycle without training wheels within the past year (likes scooter better)
- known severe to profound sensorineural hearing loss in the left ear and normal hearing in the right ear. Uses CROS hearing aid.
- Other significant history: congenital CMV, thyroid issues, and developmental delays.

Case Study 2:



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Case Study 2

- Vestibular Rehab eval:
- 1. Stand on firm surface with the eyes open: **30 seconds, no sway**
- 2. Stand on firm surface with the eyes closed: **13 seconds, stepping reaction**
- 3. Stand on compliant surface (foam) with the eyes open: **11 seconds, moderate sway followed by stepping reaction**
- 4. Stand on compliant surface (foam) with the eyes closed: **0 seconds**

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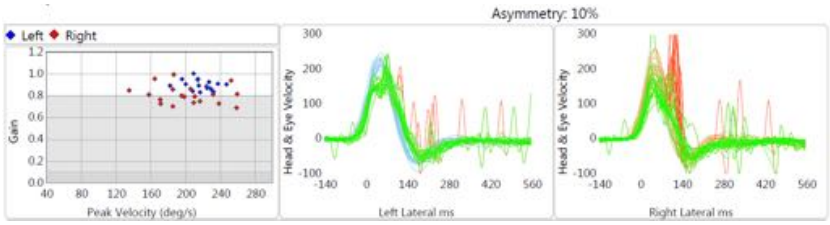
Case Study 2

- Audiology Vestibular Eval:
- **Rotary Chair**: Sinusoidal harmonic acceleration revealed low gain at 0.02 -0.32 Hz. Phase leads were recorded at all test frequencies. Step velocity testing was normal.
- **Videonystagmography**: left beating nystagmus post headshaking. Bithermal and alternating air caloric irrigations were bilaterally weak with no asymmetry.
- **Cervical VEMPs**: Absent left VEMP.
- **Ocular VEMPs:** Absent bilaterally.

Case Study 2



Case Study 2

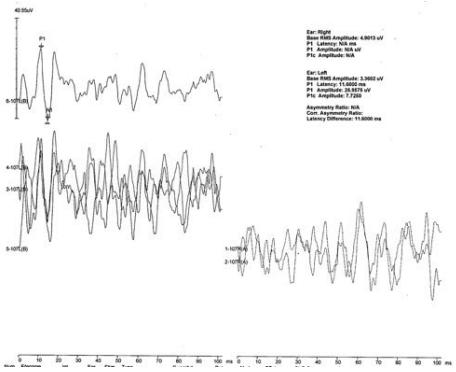
- Vestibular rehabilitation for substitution exercises
- Discussion: CMV can affect both inner ears, even though hearing was still intact on one side

Case study 3

- 8 y.o. female
- significant bilateral sensorineural hearing loss, greater in the right ear, which was identified at the age of 4 years.
- enlarged vestibular aqueducts (EVA)
- hyperopic astigmatism in both eyes and esotropia, wears glasses
- Dx with hypotonia as an infant and was evaluated for a possible mitochondrial defect.
- Her mother reported that she has always been clumsy.
- She was a late walker, age of 2.5 years.
- She reportedly loves roller coaster rides, but does not ride a bike or roller skate (can only ride a 3-wheeled scooter.)
- She also stated that 3-4 times per year, usually in the winter and spring, she will wake up coughing and will eventually start vomiting.
- She described these episodes as "my eyes feel wobbly and I throw up".

Case Study 3

- Absent calorics for ice water
- Absent VOR for all rotary chair frequencies
- VEMPs:



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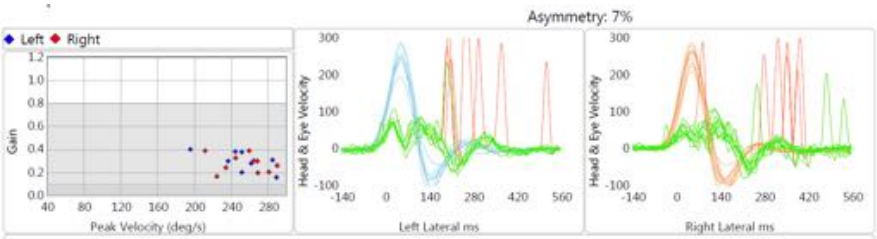
Case Study 3



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Case Study 3

- Vestibular rehab for substitution exercises and help with ADL's

Case Study 4

- 13 y.o. male
- Two episodes of dizziness that he describes as "loss of balance, room was kind of moving side to side and it's like I had motion sickness."
- First episode occurred in the summer which happened after a shower. Had to sleep right after and the symptoms were gone when he woke up the next day.
- Second episode occurred in the fall, again after a shower. He reportedly fell down into his bed, and he stated that his symptoms were still present after he woke up the next day.
- There is a family history of migraines (mother who takes medication as needed).
- He reports an occasional sinus headache (once every two months).
- Has poor hydration due to school not allowing water bottles in the classroom.
- His mother also reports that he had motion sickness younger in life and used to vomit in the car.

Case study 4

- Normal VNG
- Normal Rotary chair testing
- Prolonged VEMP on both sides

Case Study 4

Case Study 4

- He was sent back to Neurology, suspected migraine variant prolonged VEMP's and high gain on vHIT