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

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

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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
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

- 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

But Yikes!

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

**vHIT**

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

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**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….

Lateral

• Video 1 Lateral
vHIT: How to.... RALP

- Video 2 RALP

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vHIT: How to.... LARP

- Add Video 3 LARP
vHIT: Response Parameters

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

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**

<table>
<thead>
<tr>
<th>Patient Name: vHIT, 17</th>
<th>DOB: 6/25/1977</th>
<th>Gender: Female</th>
</tr>
</thead>
</table>

Lateral Impulse Test: 3/4/2015 12:06 PM  
Test Operator: Default Administrator  
Left Mean: 0.98, \( \sigma \): 0.02  
Right Mean: 1.04, \( \sigma \): 0.03  
Asymmetry: 6%

**Normal gain for adults**: Mean: 0.96  Range 0.79 – 1.20  
Curthoys, MacDougall, et al. (2016) – Sydney Clinic Norms
vHIT Interpretation: Unilateral Loss

Reduced gain – eye movement does not match head movement

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
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.

Normative Data

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

<table>
<thead>
<tr>
<th></th>
<th>SCC</th>
<th>LA</th>
<th>RP</th>
<th>RA</th>
<th>LP</th>
<th>Right Lateral</th>
<th>Left Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children (Bachmann et al., 2015)</td>
<td></td>
<td>0.80 ± 0.11</td>
<td>0.83 ± 0.09</td>
<td>0.90 ± 0.19</td>
<td>0.91 ± 0.14</td>
<td>1.04 ± 0.09</td>
<td>0.96 ± 0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.58 - 1.02)</td>
<td>(0.65 - 1.01)</td>
<td>(0.53 - 1.28)</td>
<td>(0.65 - 1.19)</td>
<td>(0.87 - 1.22)</td>
<td>(0.79 - 1.14)</td>
</tr>
<tr>
<td>Adults (Kidd et al., 2014)</td>
<td></td>
<td>0.96 ± 0.12</td>
<td>0.98 ± 0.15</td>
<td>0.95 ± 0.12</td>
<td>0.92 ± 0.17</td>
<td>1.00 ± 0.07</td>
<td>0.92 ± 0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71 - 1.20)</td>
<td>(0.68 - 1.28)</td>
<td>(0.70 - 1.19)</td>
<td>(0.58 - 1.26)</td>
<td>(0.86 - 1.14)</td>
<td>(0.80 - 1.04)</td>
</tr>
</tbody>
</table>
Normative Data

• Test time comparison

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Lateral</th>
<th>LARP</th>
<th>RALP</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-6</td>
<td>2.00 ± 0.46</td>
<td>3.23 ± 2.18</td>
<td>2.47 ± 1.40</td>
</tr>
<tr>
<td>7-9</td>
<td>1.32 ± 0.22</td>
<td>2.01 ± 0.47</td>
<td>1.32 ± 0.40</td>
</tr>
<tr>
<td>10-12</td>
<td>1.18 ± 0.21</td>
<td>2.02 ± 1.27</td>
<td>1.40 ± 0.43</td>
</tr>
<tr>
<td>Adults</td>
<td>1.24 ± 0.30</td>
<td>1.49 ± 1.00</td>
<td>1.26 ± 0.46</td>
</tr>
</tbody>
</table>

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

Positioning: Solution
Use of Footstool
Positioning: Solution
Sitting on Parent’s Lap

Video 4 Parent’s Lap

Positioning: Solution
Criss-cross applesauce
Goggle Placement: Challenges

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

Goggle Placement: Solution Instructions

- Video 5 Goggle Instructions
Goggle Placement: Solution
Retention

AudiologyOnline

Goggle Placement: Solution
Retention

AudiologyOnline
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

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Sticker Gain</th>
<th>Video Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 6</td>
<td>0.90</td>
<td>0.95</td>
</tr>
<tr>
<td>7 to 9</td>
<td>1.00</td>
<td>1.05</td>
</tr>
<tr>
<td>10 to 12</td>
<td>1.10</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Video Study Findings: Time for sticker vs. video Testing

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Sticker Time (sec)</th>
<th>Video Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 6</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>7 to 9</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>10 to 12</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>
Video Study Findings: Asymmetry

Fig 6. Sticker vs. Video Asymmetry

Sticker Asymmetry (%)

Video Asymmetry (%)

Video/Sticker comparison

• Sticker

• Video
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
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 ???
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:

- 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**
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

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

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