Head Impulse Testing
from visual observation
to video recording

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History

Beginning – 1988 – Head Impulse

Goggles vs Visual Observation

What advantages does vHIT have over visual observation?

- Can identify both overt and covert catch-up saccades
- Sensitivity is estimated at 70% for visual observation. vHIT Impulse increased the sensitivity for identifying catch-up (refixation) saccades.
- Reduction in false negative (identifying patients as normal who are truly abnormal)
- Better patient comfort during testing
- Validates that the head impulse is performed properly
- Objective Analysis with normative data
- Documented head impulse test results

To reduce goggle slippage during the rapid head impulse test we have developed tight fitting and lightweight (~60g) goggles with a high speed camera (250 Hz) and miniaturised 6DOF inertial sensors.


Goggle Prototype to ICS Impulse

Low Weight, Low Mass, No Torque

Less mass, close to the head

More mass, protruding away from the head

Low Weight, Low Mass, No Torque
ICS Impulse
Common VNG Goggles
Goggles intended for videonystagmography are too heavy, result in too much torque and do not fit close to the face. All these attributes make performing a proper head impulse impossible.

Prototype Goggle vs Scleral Search Coil
- Horizontal HIT was recorded simultaneously with vHIT (250 Hz) and search coils (1,000 Hz) in 8 normal subjects, 6 patients with vestibular neuritis, 1 patient after unilateral intratympanic gentamicin, and 1 patient with bilateral gentamicin vestibulotoxicity.
- Conclusions: The video head impulse test is equivalent to search coils in identifying peripheral vestibular deficits but easier to use in clinics, even in patients with acute vestibular neuritis.

- Conclusions: vHIT detects dysfunction of individual vertical semicircular canals in vestibular patients as accurately as scleral search coils. Unlike search coils, vHIT is non-invasive, easy to use and hence practical in clinics.

A new Powerful Gold Standard in VOR
- Built on the work of Drs. Halmagyi & Curthoys
- Impulse is the only device validated against Scleral Search Coils for all 6 canals
Face Cushion

Goals of Face Cushion Design
- Disposable
- Inexpensive
- No-slippage
- Fits all faces

More History - Software
Quality Data Collection & Ease of Use

- Data Collection
  - Assuring a high frame rate
  - Collection and Analysis Algorithms
    - Making sure only good data is analyzed
    - Identification of saccades
  - Gain measurement
- Quality indicators
  - Training curves
  - Operator feedback
  - Training materials

Frame rate

- ICS Impulse camera – 250 Hz (frames per second)
- Remember VNG responses are slow and gentle. A quick head impulse results in a quick eye movement. Catch-up saccades are also fast.
- "Researchers using scleral search coils record eye movements at 1kHz or even 5kHz so they always thought video was far too slow until we got their attention at 250fps. We think 250Hz is the sweet spot in the trade off between frame rate (temporal resolution) and image pixels (spatial resolution). Recording saccades at a low frame rate can distort their shape or ignore them all together. At 120fps you often get one sample point (or none) during a saccade so it’s shape becomes just a single spike - like noise, its amplitude becomes totally dependant (chance) on when the sample was taken (near peak velocity or not), and it is more difficult for desaccading algorithms to recognize." Hamish McDougall

Frame rate

Legend: A more headfirst, than a lateral, fast single eye movement
Frame rate

The end user should be aware of the frame rate during collection and afterward. The computer can have a direct impact on the frame rate. If the frame rate drops below 219 on Impulse the data will be rejected.

Algorithms

Two algorithms assure only good data is analyzed.

Collection Algorithm:
The collection algorithm looks at all 250 samples. We look at the velocities of the eye and head during collection for each head impulse. The data collected is compared to boundary conditions of a “proper” head impulse (training curves). The “proper” head impulse is based on 1000s of head impulses collected during research by our collaborators in Australia. The head must have a shape similar to the training curves. The eye velocity must be within a particular boundary which is comparable to how the eye should move during a “proper” head impulse. If the head and/or eye are outside of these boundaries then the impulse is rejected. If they are inside these boundaries then the impulse is accepted.
Algorithms

Two algorithms assure only good data is analyzed.

Analysis Algorithm:
- The analysis algorithm looks at 175 samples. This eliminates data that is not useful at the beginning or end of the head impulse. Again the data analyzed is compared to boundary conditions of a “proper” head impulse. The “proper” head impulse is based on 1000s of head impulses collected during research by our collaborators in Australia. The head must have a shape similar to the training curves. The eye velocity must be within a particular boundary which is comparable to how the eye should move during a “proper” head impulse. If the head and/or eye are outside of these boundaries then the impulse is rejected. If they are inside these boundaries then the impulse is accepted. The main difference between the two algorithms is that during the analysis algorithm the head data is run through a velocity peak detection algorithm to determine exactly where the peak of the head impulse resides. This is needed during the gain calculation.

Gain

- Instantaneous gain was used initially but based on a lot of data collection and analysis it was discovered that a “bump artifact” was occurring which interferes with gain calculation. These traditional VOR gain measurement at peak head acceleration led to falsely high gains with video compared to search coils.

What cause this artifact? Loose goggles, touching the goggle or strap, subject might have a face shape that doesn’t fit the goggles well, or a particularly compliant face, a ‘big hair’ style, or ...
Gain

• It was decided that by measuring gain over a wide window from the beginning of the head impulse until the head velocity returns to 0°/s a more accurate gain measurement was possible. This resulted in similar gain calculations for video and search coils.

Desaccading

• However, covert saccades during the head impulses led to falsely high VOR gain values for both methods. Therefore, the catch-up saccades are first detected and excluded from the analysis.

• Gains calculated with desaccaded eye velocity were very similar for video and search coils and quite comparable to the traditional gain measurement method for search coils around peak head acceleration.


A new Powerful Gold Standard in VOR

• Built on the work of Drs. Halmagyi & Curthoys
• Impulse is the only device validated against Scleral Search Coils for all 6 canals
Training Curves & Operator Feedback
Ensuring proper head impulses are performed

Training Materials
Each system comes with a Quick Guide and Training DVD

Performing a Proper Head Impulse
Pupil Detection

Setup & Calibration
Patient sitting 1 meter from fixation dot
Lasers are built into the goggle
Calibration check

Head Impulse maneuver
10-15 degrees (smaller for LARP/RALP)
150-200 deg/sec is ideal
Performing a head impulse and more

www.icsimpulse.com

Analysis

<table>
<thead>
<tr>
<th>Result</th>
<th>Average Gain</th>
<th>Gain Graph</th>
<th>SD Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Right 0.87 SD 0.10</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
</tr>
<tr>
<td>Overt</td>
<td>Left 0.41 SD 0.08</td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
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<tr>
<td>Covert</td>
<td>Right 0.33 SD 0.09</td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>
Diagnostic Benefit

Incorporating into your workflow

- Determine if the disorder is central or peripheral
- Only test for the anterior and posterior canals
- Ability to test acute, young and elderly patients
- Determine if the disorder is affecting the inferior or superior branch of the vestibular nerve
- Determine if the disorder is occurring in the canal
- Test the VOR at frequencies higher than caloric or rotary chair (in a range more typical of everyday use)
- Test young children using as a monocular Frenzel goggle
- Ability to perform serial testing to monitor changes
  - Benefit of rehab - compensation
  - Monitor gentamicin treatments

Head Impulse vs Caloric

- Ear-specific
- Detects abnormalities in all six semicircular canals in cases with peripheral vestibular loss (Lateral, Anterior and Posterior)
- Tests with stimuli replicating the patient's everyday situations (physiological stimulus)
- Stimulus does not persist between tests
- Ability to test patients even if they have middle ear disorders
- Ability to test patients who do not tolerate calorics (young children, elderly, or patients with severe hearing loss)

- Ear-specific
- Detects cases of peripheral vestibular loss in Lateral semicircular canal
- Tests at Low Frequencies (~0.025 Hz)
- Stimulus can persist between irrigations especially if not performed properly
- Middle ear disorder may prohibit performing the test
- Some patients will not tolerate calorics testing or will not allow the caloric test to be completed
Head Impulse vs Rotary Chair

**Advantages of Rotary Chair and why it is often paired with Calorics**
- Can test patients with middle ear disorder
- Can test difficult to test patients including young patients and patients that will not tolerate calorics
- Distinguish between true bilateral vestibular lesions and false-positive caloric reduction
- Evaluate changes in the VOR function over time (serial testing)
- Ability to use off-axis or eccentric rotation to assess utricular function
- Can test visual-vestibular interaction

**Disadvantages of Rotary Chair**
- Test canals simultaneously (not ear specific so cannot distinguish unilateral from bilateral disorder)
- Only detects cases of peripheral vestibular loss in lateral semicircular canals with the exception of eccentric rotation for utricular testing.
- Is mostly insensitive to common vestibular lesions which are mostly unilateral in origin
- Test can result in adverse reaction
- Total body rotation assumes the head is completely fixed and therefore the stimulus delivered to the body is the same as delivered to the head. This assumption becomes unreliable at frequencies above 1 Hz.
- Physical space needed for a rotary chair and cost of the equipment can be a limitation

**ICS Impulse**
- Site of lesion specific
- Tests all 6 semicircular canals
- Identifies unilateral and bilateral vestibular disorders
- No adverse reactions even in acute patients
- Tests at frequencies similar to usage in everyday life
- Portable and less expensive
Right Inferior Vestibular Neuritis

Left Neurectomy and Right Meniere’s

Documenting Compensation
How does vHIT affect my treatment?

• Impulse says within seconds (qualitatively) or minutes (quantitatively) if the patient has a dramatic loss of function. This helps me decide whether to head for physical therapy, or whether the patient is having a stroke or not.

• It is a pure test of peripheral function. So many patients that ENTs get with dizziness, the question is: “Is this a central or a peripheral problem?”

• Impulse is impervious to many of the issues with calorics (attention, temperature transfer, central compensation).

• There is much less chance for variability than in rotational chair and calorics. There is astounding variability when directly comparing rotational chair or caloric responses from different labs in the same person leading to many improper diagnoses.

• It is MUCH more quantitative than any other method that we have.

ICS Impulse the only vHIT system approved by.
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