Head Impulse Testing

from visual observation
to video recording

Wendy Crumley-Welsh M.S. CCC-A
Product Manager

History

Beginning – 1988 – Head Impulse

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

Beginning – 1988 – Head Impulse

Fig 1.—Normal gaze fixation during rapid head turn toward intact side. A and B, With her face turned a little to the right and her eyes fixed on a distant target, patient (professional model) waits for her head to be moved rapidly to left by examiner. C, After leftward head movement, gaze is still fixed on target so that no refixation saccades are required.

Fig 3.—Clinical sign of right canal paresis: abnormal gaze fixation during rapid head turn toward lesioned side. A, With her face turned a little to left and with her eyes fixed on a distant target, patient (professional model) waits for her head to be moved rapidly to the right. B, Following rightward head turn, it becomes evident that gaze has shifted during head turn with head to right. C, Leftward or compensatory saccade is now required to refix gaze.

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

Goggles vs Visual Observation

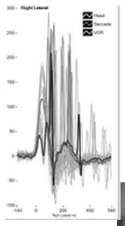
What advantages does vHIT have over visual observation?

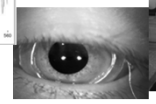
- Can identify both overt and covert catch-up saccades
- Sensitivity is estimated at 70% for visual observation*. ICS Impulse increased the sensitivity for identifying catch-up (refixation) saccades.
- Reduction in false negative (identifying patients as normal who are truly abnormal)
- Better patient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

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

Scleral Search Coils vs Visual Observation

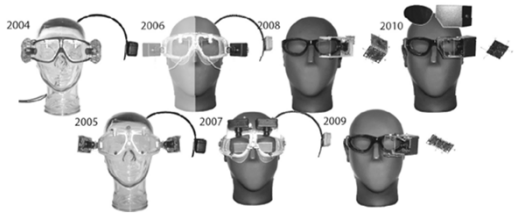
Discovered covert saccades





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

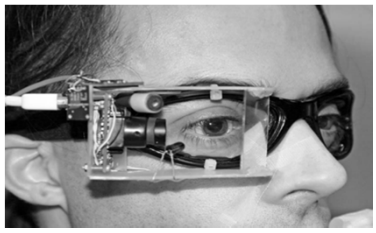
Moving beyond the Scleral Search Coil



" 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 miniaturized 6DOF inertial sensors ." Hamish McDougall

Hamish McDougall, Konrad Weber, Leigh McGarvie, Leonardo Manzari, Michael Halmagyi, Ian Curthoys

Goggle Prototype to ICS Impulse



Hamish McDougall, Konrad Weber, Leigh McGarvie, Leonardo Manzari, Michael Halmagyi, Ian Curthoys

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

ICS Impulse goggles weigh 60 gram. The profile is close to the face eliminating torque. The fit is tight to the face. All of these attributes eliminate goggle movement artifact.

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

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

- 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.

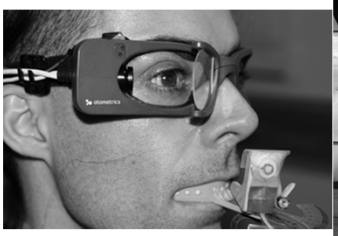
- **Conclusions: The video head impulse test is equivalent to search coils in identifying peripheral vestibular deficits but easier to use in clinics, even in patients with acute vestibular neuritis.**

MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP (2013) The video head impulse test detects vertical semicircular canal disfunction. PLOS one 8(4):e61488.

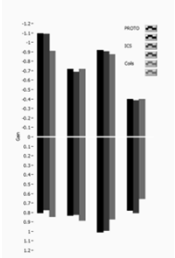
- **Conclusions: vHIT detects dysfunction of individual vertical semicircular canals in vestibular patients as accurately as scleral search coils. Unlike search coils, vHIT is non-invasive, easy to use and hence practical in clinics.**

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



Subject	P1		P1	P2		P2	P3		P3	P4		P4
Direction	L		R	L		R	L		R	L		R
PROTO		0.80	1.09		0.83	0.72		1.01	0.92		0.78	0.40
ICS		0.77	1.09		0.82	0.69		0.99	0.90		0.80	0.38
COILS		0.85	0.91		0.89	0.72		0.87	0.87		0.65	0.40
proto to ICS		0.03	0.00		0.01	0.03		0.02	0.02*		0.02	0.02
proto to coil		0.05*	0.18		0.06	0.00		0.14	0.05		0.13	0.00
ics to coil		0.08*	0.18		0.07	0.03		0.12	0.03		0.15	0.02
Diagnosis	Lateral medullary syndrome			Right Inferior Vestibular Neuritis			Bilateral Cerebellar Stroke			Pontine Stroke		



Face Cushion

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

More History - Software

Quality Data Collection & Ease of Use

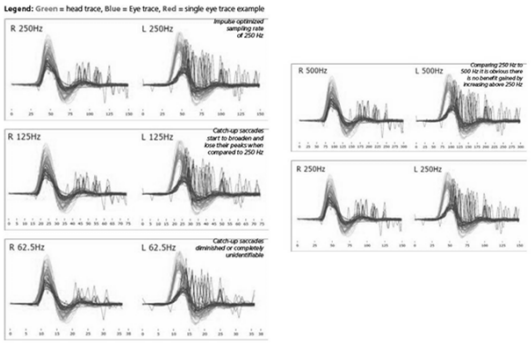
- Data Collection
  - Assuring a high frame rate
  - Collection and Analysis Algorithms
    - Making sure only good data is analyzed
    - Identification of Saccades
  - Gain measurement
- Quality indicators
  - Training curves
  - Operator feedback
  - Training materials

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.

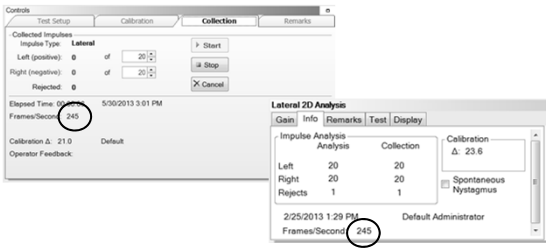
- "Researchers using scleral search coils record eye movements at 1kHz or even 5kHz so they always thought video was far too slow until we got their attention at 250fps. We think 250Hz is the sweet spot in the trade off between frame rate (temporal resolution) and image pixels (spatial resolution). Recording 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, it's 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



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.



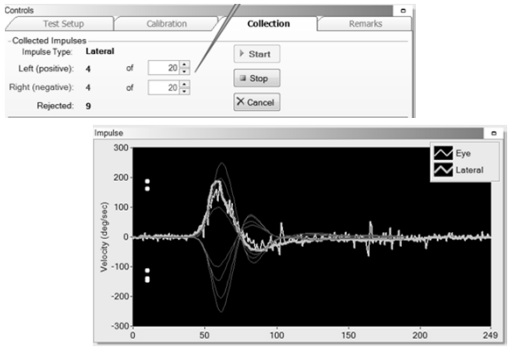
Algorithms

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.

Collection Algorithm



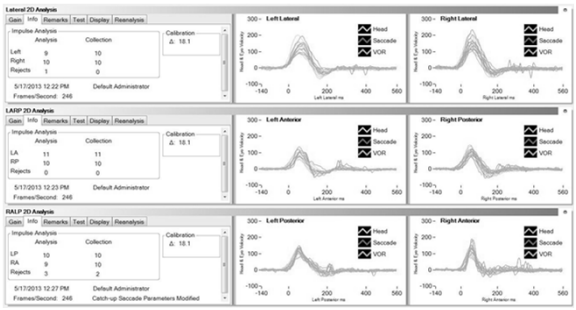
Algorithms

Two algorithms assure only good data is analyzed.

Analysis Algorithm:

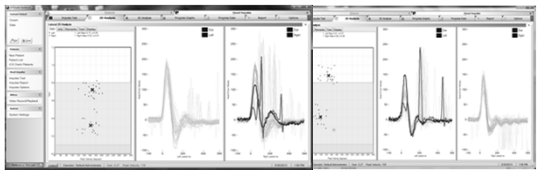
- The analysis algorithm looks at 175 samples. This eliminates data that is not useful at the beginning or end of the head impulse. Again the data analyzed is compared to boundary conditions of a "proper" head impulse. The "proper" head impulse is based on 1000s of head impulses collected during research 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.

Analysis Algorithms



Gain

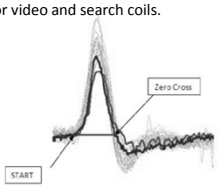
- Instantaneous gain was used initially but based on a lot of data collection and analysis it was discovered that a "bump artifact" was occurring which interferes with gain calculation. These traditional VOR gain measurement at peak head acceleration led to falsely high gains with video compared to search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



There are 175 samples per analyzed impulse. We take each sample from the start to the zero-cross for the head movement. We sum the amplitudes of each of these samples. This gives us one value for the head. We repeat the process for the eye movement giving us one value for the eye.

Gain = eye-sum divided by the head-sum.

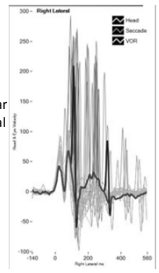
Note that for the sake of this calculation, the eye tracing is first de-saccaded.

In summary, our present gain calculation is based on area under the (de-saccaded) eye velocity vs area under the head velocity.

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.

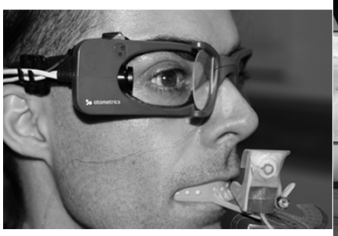
- Gains calculated with desaccaded eye velocity were very similar for video and search coils and quite comparable to the traditional gain measurement method for search coils around peak head acceleration.



MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP (2013) The video head impulse test detects vertical semicircular canal disfunction. PLOS one 8(4):e61488.

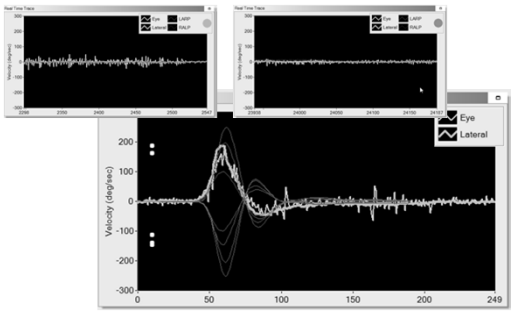
A new Powerful Gold Standard in VOR

- Built on the work of Drs. Halmagyi & Curthoys
- Impulse is the only device validated against Scleral Search Coils for all 6 canals

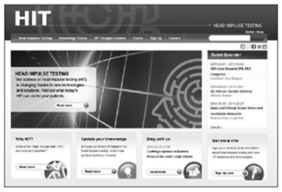


Training Curves & Operator Feedback

Ensuring proper head impulses are performed



Training Materials



www.icsimpulse.com

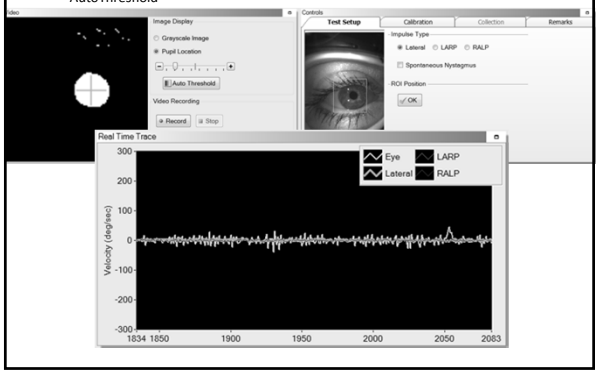
www.headimpulse.com

Each system comes with a Quick Guide and Training DVD

Performing a Proper Head Impulse

Pupil Detection

AutoThreshold

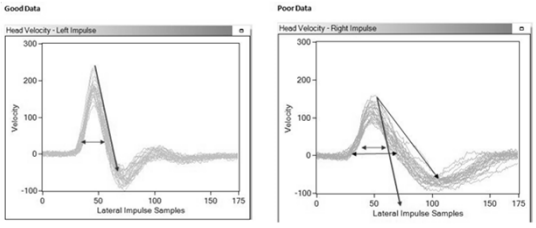


Setup & Calibration

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

Head Impulse maneuver

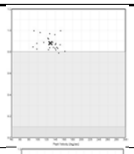
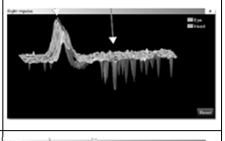
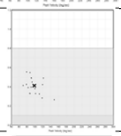
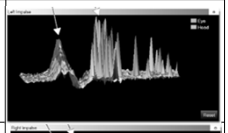
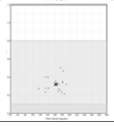
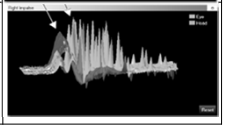
10-15 degrees (smaller for LARP/RALP)
150-200 deg/sec is ideal



Performing a head impulse and more

www.icsimpulse.com

Analysis

Result	Average Gain	Gain Graph	3D Graph
Normal	Right 0.87 SD 0.10		
Overt	Left 0.41 SD 0.08		
Covert	Right 0.33 SD 0.09		

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 gentamycin 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 caloric 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

ICS Impulse

- 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)
- Can test visual-vestibular interaction

Head Impulse vs Rotary Chair

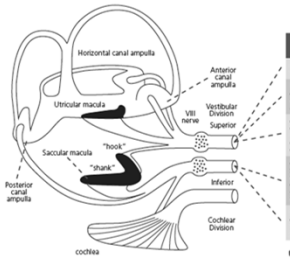
Disadvantages of Rotary Chair

- 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

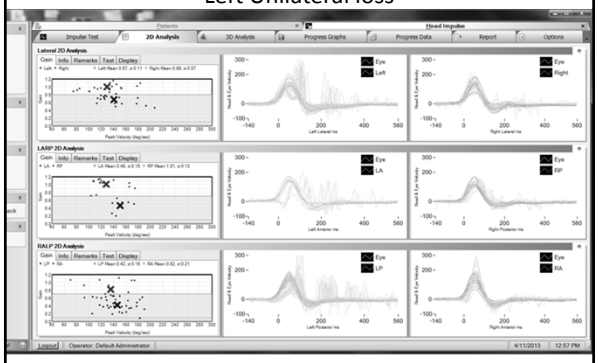
The Complete Test of the Vestibular Peripheral System



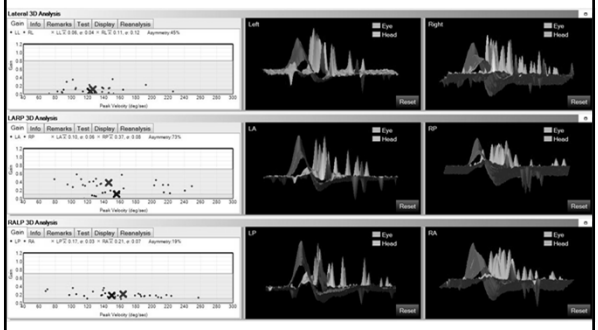
Clinical Test*	Healthy Subjects	Superior Vestibular Neuritis	Inferior Vestibular Neuritis	Unilateral Vestibular Loss
Horizontal head turn to ipsilateral horizontal canal	✔	✘	✔	✘
Pitch head impulse test in the plane of the ipsilateral anterior canal, head turn nose down - tests ipsilateral anterior canal	✔	✘	✔	✘
oVEMP n10 beneath the contralateral eye to bone conducted vibration at FZ, or air-conducted sound of one ear - tests utricular macula of the ear opposite to the eye	✔	✘	✔	✘
cVEMP p13-n23 over ipsilateral sternocleidomastoid (SCM) muscle to bone conducted vibration at Fz, or air-conducted sound of one ear - tests saccular macula of the ear on the same side	✔	✔	✘	✘
Pitch head impulse in the plane of the ipsilateral posterior canal, head turn nose up - tests ipsilateral posterior canal	✔	✔	✘	✘

✔ = Normal Response ✘ = Abnormal Response

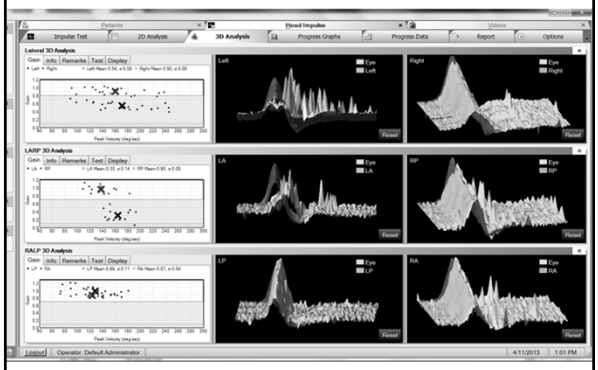
Left Unilateral loss



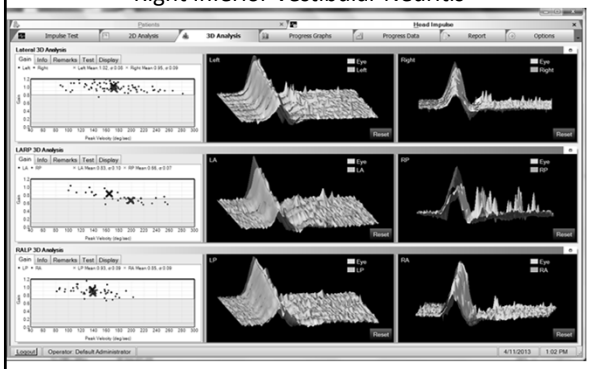
Bilateral loss



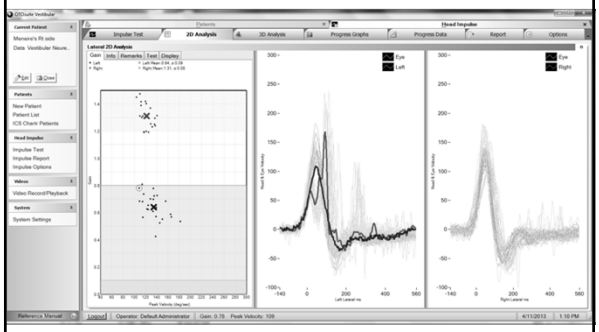
Left Superior Vestibular Neuritis



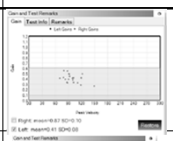
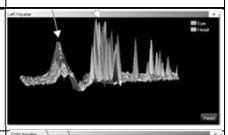
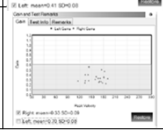
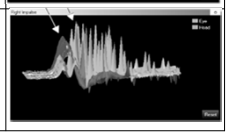
Right Inferior Vestibular Neuritis



Left Neurectomy and Right Meniere's



Documenting Compensation

Result	Average Gain	Gain Graph	3D Graph
Overt	Left 0.41 SD 0.08		
Covert	Right 0.33 SD 0.09		

Passive - someone moves patient's head
Active – patient moves their own head

Schubert MC, Hall CD, Das V, Tusa RJ & Herdman SJ (2009) Oculomotor Strategies and Their Effect on Reducing Gaze Position Error. Otology & Neurology

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..

Stay updated or learn more…