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"The Current State of Video Head Impulse Testing"

Devin L. McCaslin, Ph.D.
Division of Audiology
Division of Vestibular Sciences
Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences
Vanderbilt University Medical Center

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Disclaimers

- I have consulted with
  - Oticon Medical
  - Interacoustics
  - Intelligent Hearing Systems

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Learning Outcomes

- After this course, participants will be able to:
  - 1) Describe the measurement parameters of the vHIT.
  - 2)Describe the clinical utility of the vHIT in assessing peripheral unilateral impairments
  - 3)Describe how the vHIT can detect central impairments.

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Introduction

- We cannot use imaging or any other sort of anatomical evidence to confirm an impairment in the vestibular system
- The clinicians interpretation of findings from tests of peripheral vestibular function are critical to achieving a correct diagnosis.

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Introduction

- The clinical assessment of the peripheral vestibular system often consists of comparing the level of function from similar end-organs.
- In order to correctly interpret tests of vestibular function, the clinician must thoroughly understand the anatomical and physiological underpinnings of the tests.

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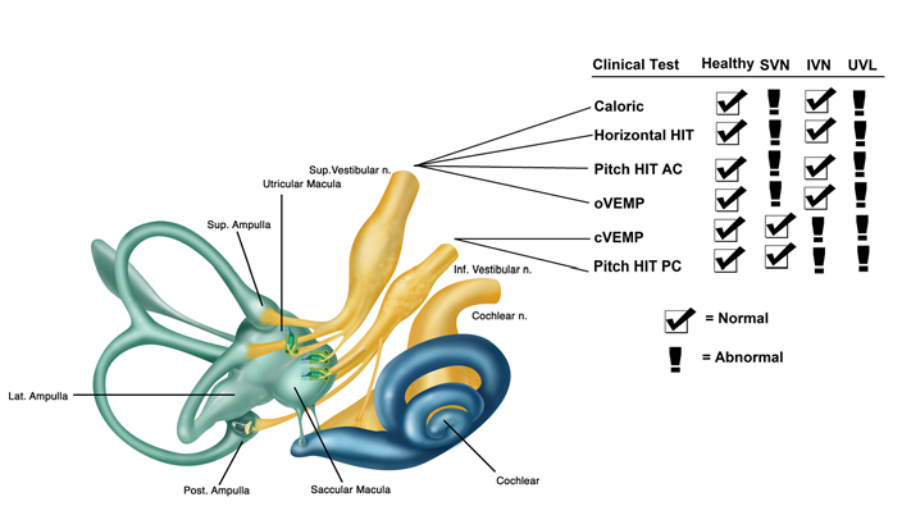
Patterns



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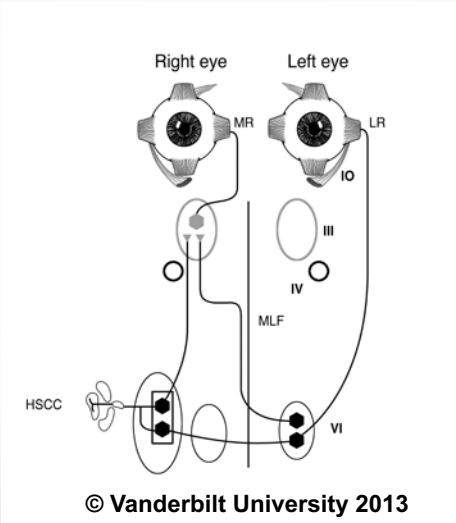
Semi-Circular Canals



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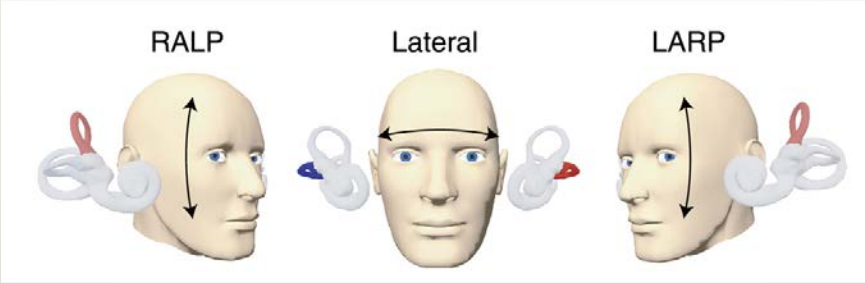
Ewald's Laws



MacDougall et al., *Otology& Neurotology*, 2013

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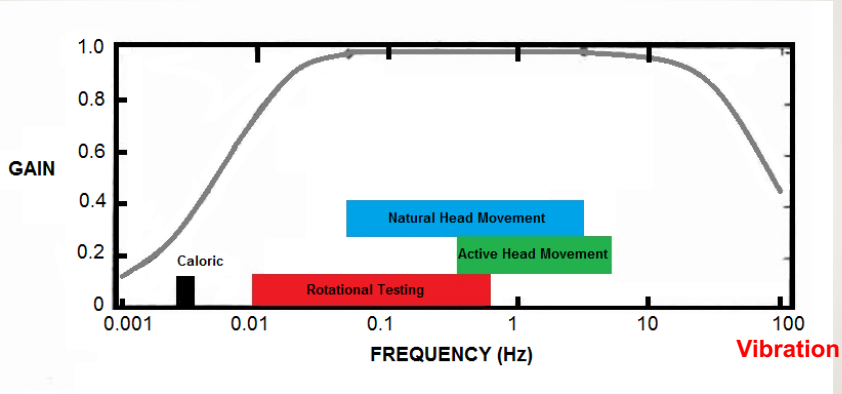
VOR: Frequency and Gain

Gain is best above .1 Hz and poorest below



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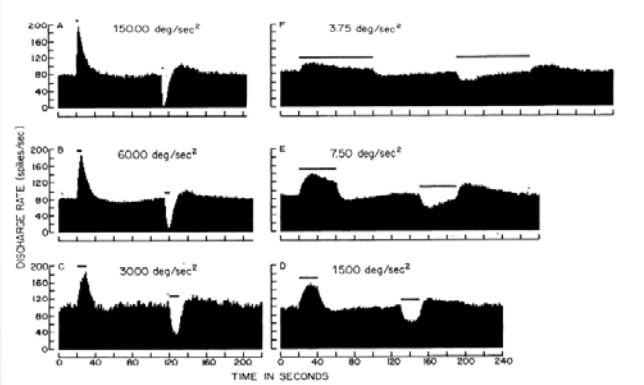
Responses from the Semicircular Canal Afferents



The dynamic range is different for excitatory and inhibitory responses (Ewald 1892).

Goldberg and Fernandez, 1971

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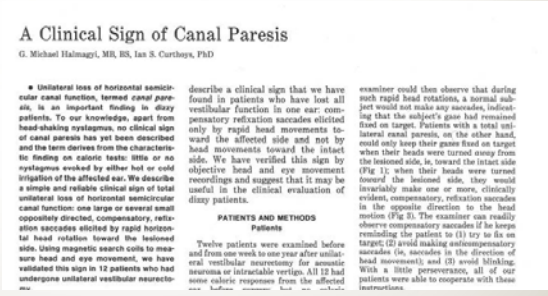
Background of the Head Impulse Test

- Halmagyi and Curthoys (1988)
- Doll's eye test



A Clinical Sign of Canal Paresis

G. Michael Halmagyi, MB, BS, Ian S. Curthoys, PhD

● Unilateral loss of horizontal semicircular canal function, termed *canal paresis*, is an important finding in dizzy patients. To our knowledge, apart from head-shaking nystagmus, no clinical sign of canal paresis has yet been described and the term derives from the characteristic finding on caloric tests: little or no nystagmus evoked by either hot or cold irrigation of the affected ear. We describe a simple and reliable clinical sign of total unilateral loss of horizontal semicircular canal function: one large or several small oppositely directed, compensatory, refixation saccades elicited by rapid horizontal head rotation toward the lesioned side. Using magnetic search coils to measure head and eye movement, we have validated this sign in 12 patients who had undergone unilateral vestibular neurectomy.

describe a clinical sign that we have found in patients who have lost all vestibular function in one ear: compensatory refixation saccades elicited only by rapid head movements toward the affected side and not by head movements toward the intact side. We have verified this sign by objective head and eye movement recordings and suggest that it may be useful in the clinical evaluation of dizzy patients.

PATIENTS AND METHODS

Patients

Twelve patients were examined before and from one week to one year after unilateral vestibular neurectomy for acoustic neuroma or intractable vertigo. All 12 had some caloric responses from the affected

examiner could then observe that during such rapid head rotations, a normal subject would not make any saccades, indicating that the subject's gaze had remained fixed on target. Patients with a total unilateral canal paresis, on the other hand, could only keep their gaze fixed on target when their heads were turned *away* from the lesioned side, ie, toward the intact side (Fig 1); when their heads were turned *toward* the lesioned side, they would invariably make one or more, clinically evident, compensatory, refixation saccades in the opposite direction to the head motion (Fig 3). The examiner can readily observe compensatory saccades if he keeps reminding the patient to (1) try to fix on target; (2) avoid making anticompensatory saccades (ie, saccades in the direction of head movement); and (3) avoid blinking. With a little perseverance, all of our patients were able to cooperate with these instructions.

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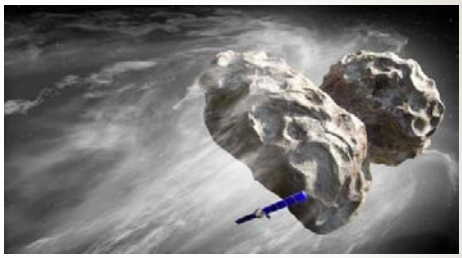

Then…. **Now…**

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HIT Technique

- Patients are asked to maintain gaze on an earth-fixed target (1 meter away)
- The head is grasped by the examiner and moved in a high acceleration low amplitude movement (10-20 degrees-horiz).
- A patient with intact vestibular function will be able to maintain their gaze on the target.
- A patient with an impairment will generate one of two types of saccades.

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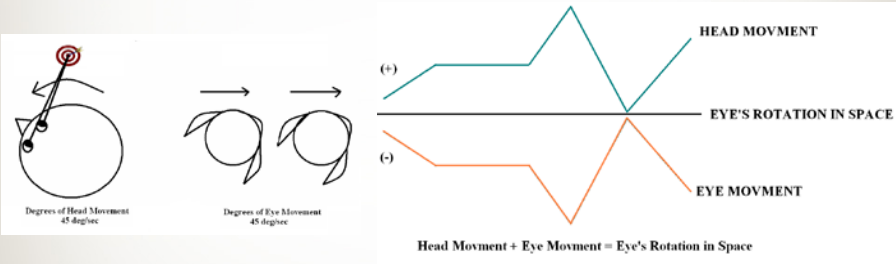
Vestibulo-ocular Reflex (VOR)



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"Catch-up saccade"

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Normal HIT

Abnormal HIT

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Technique

- Must be an abrupt impulse/acceleration (i.e. > 50 degrees per second) since the oculomotor system can compensate for head movement at low frequencies).
- When a head velocity exceeds approximately 100 degrees per second the VOR is the sole contributor to the corresponding eye movement.

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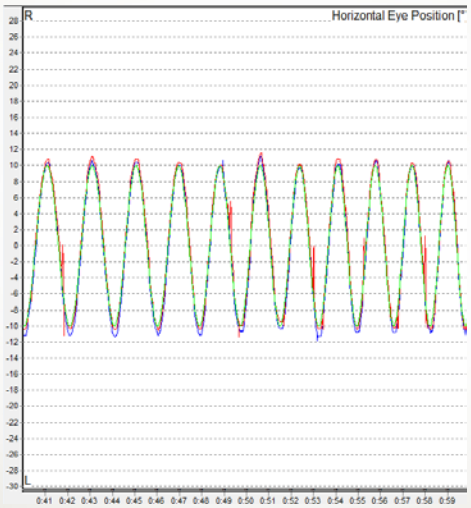
Technique is Critical



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Why it matters…

- Low noise of the coil method allows for high spatial (< 1 degree) and temporal (less than 1 msec) resolution.

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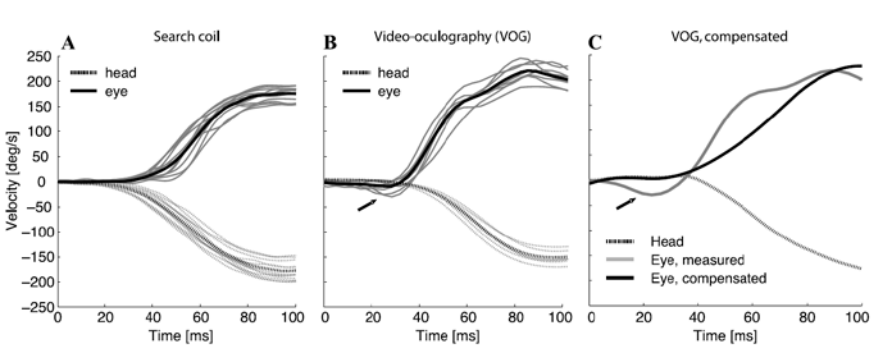
Comparison of Techniques



Bartl et al., *Annals of the New York Academy of Sciences*, 2009

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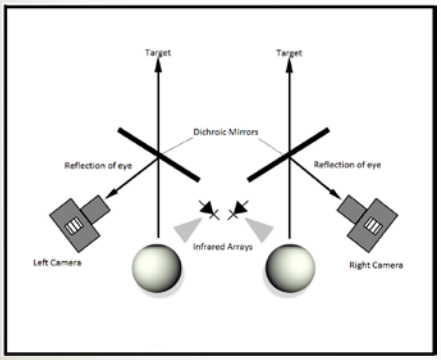
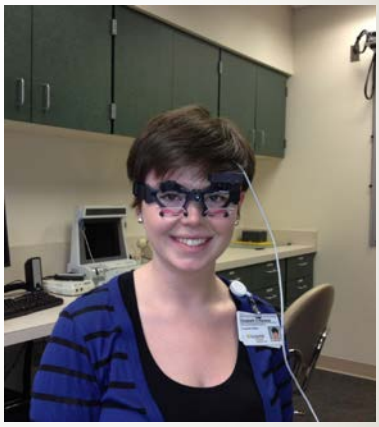
Video-oculography





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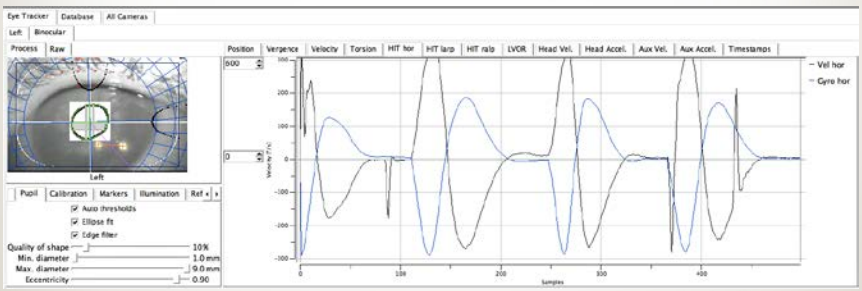
What is Measured?

- Position of the eye
- Head velocity in 3-dimensional space



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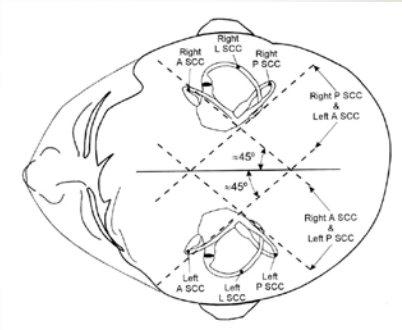
RALP and LARP

- Spatial Arrangements:
  - The three SCC are at right angles to each other so that they lie in the three planes of space (corner).



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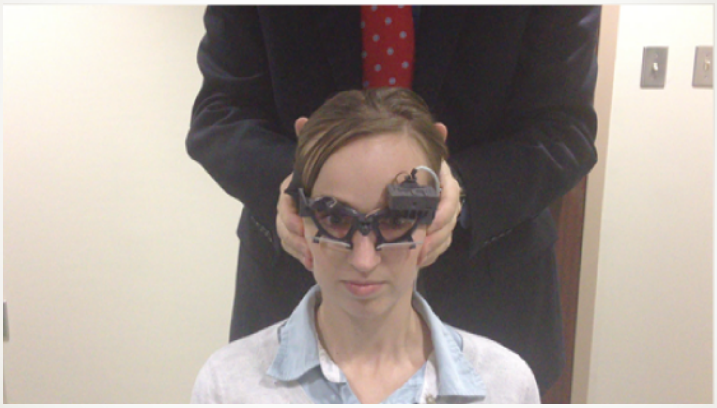

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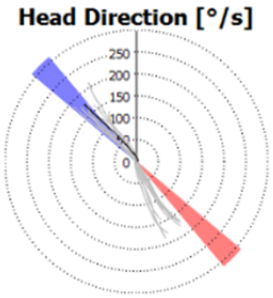
Vertical HIT



The correct plane for LARP's

The correct plane for RALP's

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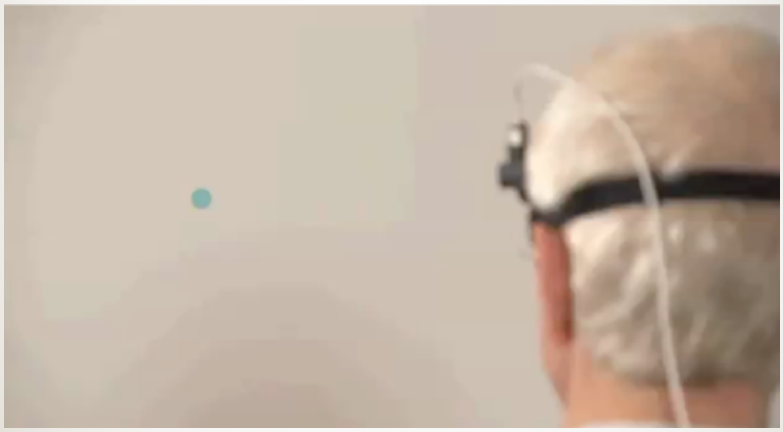
Calibration for Vertical Channels



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Right Anterior - Left Posterior

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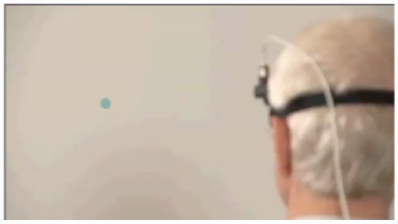
Left Anterior –Right Posterior



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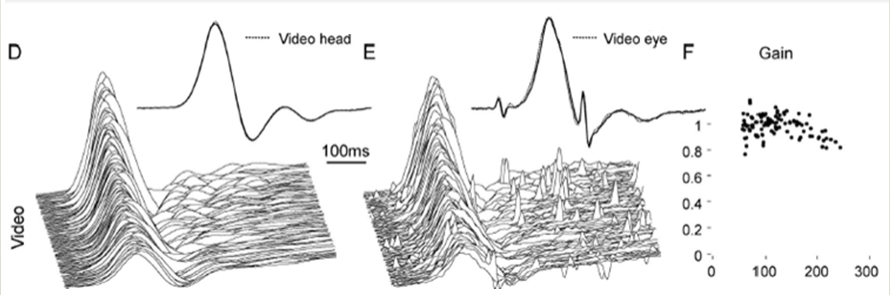
MacDougall et al. 2009
"The video head impulse test"

Normal <u>head</u> velocity **Normal <u>eye</u> velocity**



Eyes move perfectly out-of-phase with the head with few, if any, catch-up saccades

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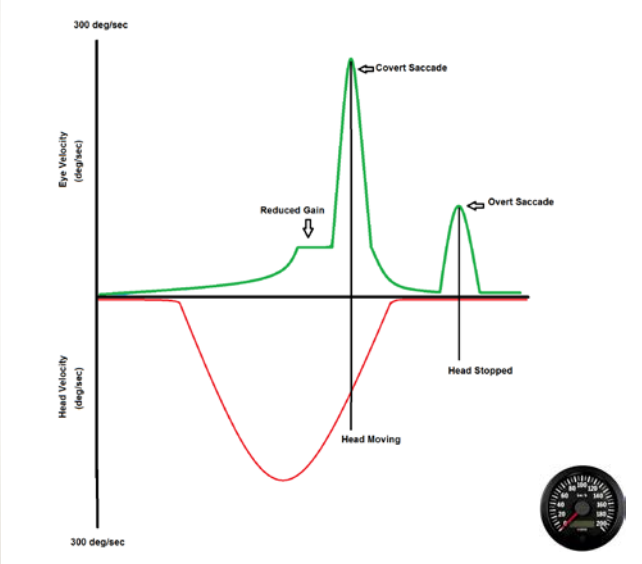
Eye and Head Velocity



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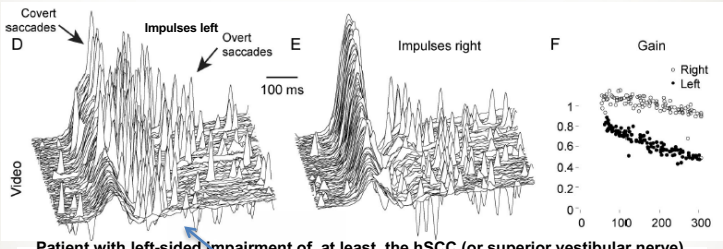
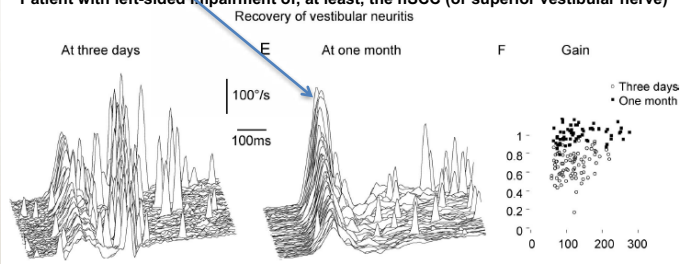
MacDougall et al. 2009
"The video head impulse test"



Patient with left-sided impairment of, at least, the hSCC (or superior vestibular nerve)

Recovery of vestibular neuritis



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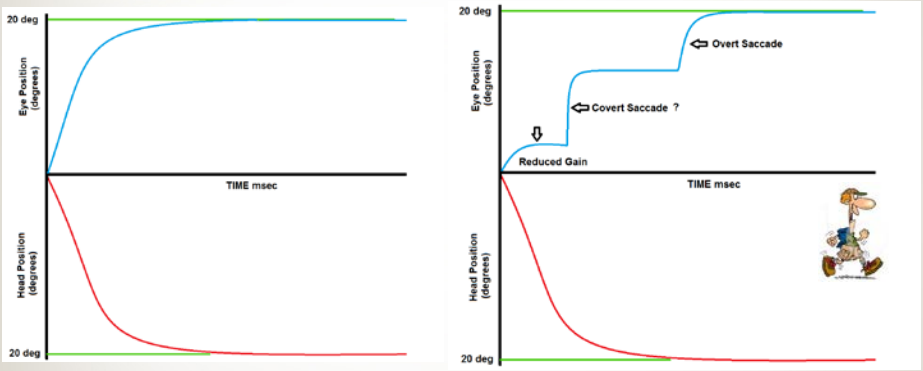
Eye and Head Position



NORMAL ABNORMAL

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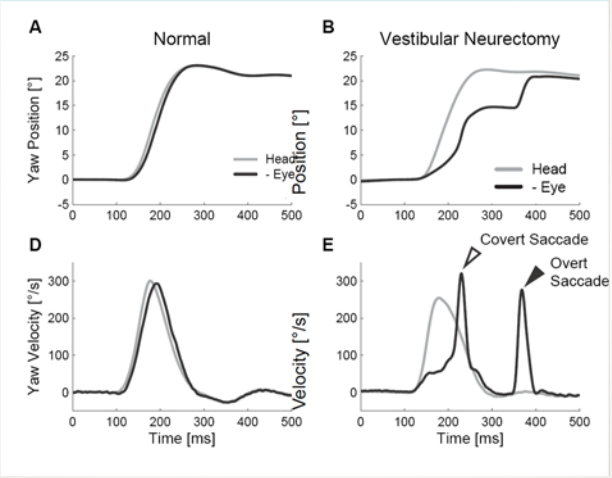
Saccade Classification



Weber et al., *Neurology*, 2008

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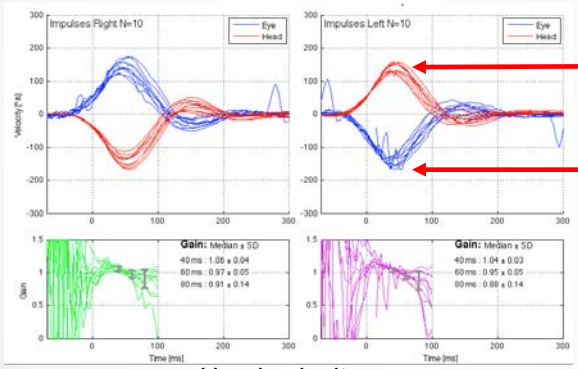
Calculation of VOR Gain



Head Velocity

Eye Velocity

Head velocity

Eye Velocity

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Factors Considered for Interpretation

- Vestibulo-ocular Reflex Gain
  - Speed or position of the eye vs. head
- Catch-up saccades (direction, velocity, timing)
  - Overt
  - Covert
- Gain Asymmetry
  - Impulses to the left vs. right

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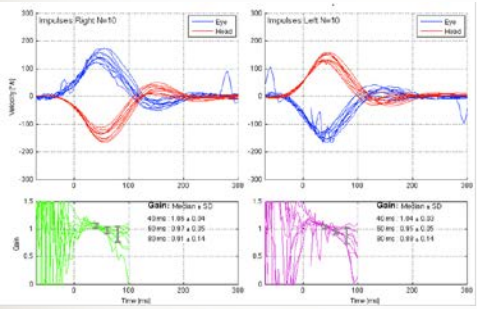
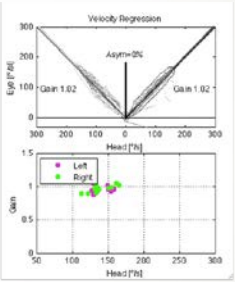
Factors Considered for Interpretation





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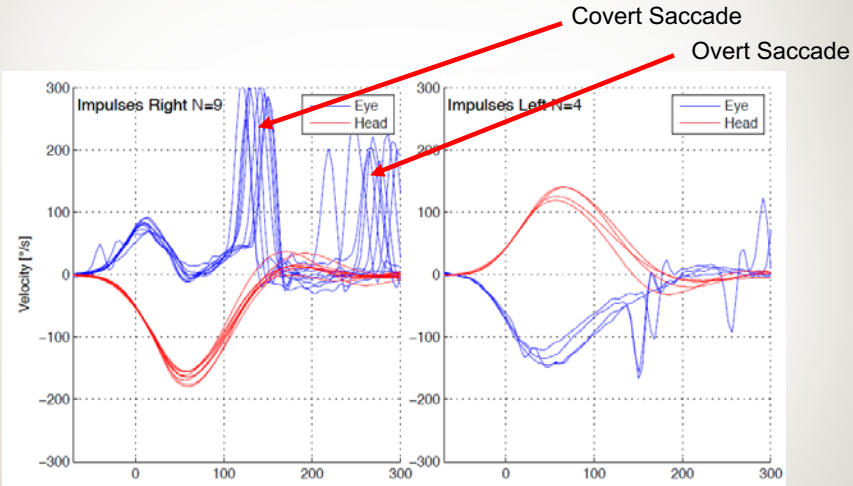
Abnormal vHIT



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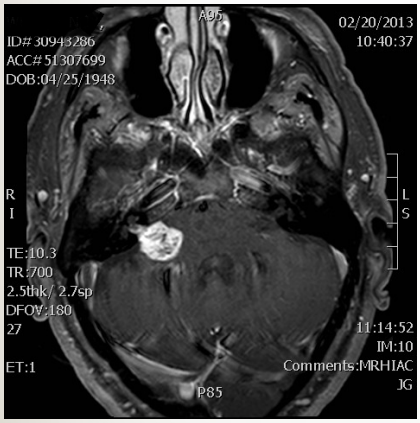
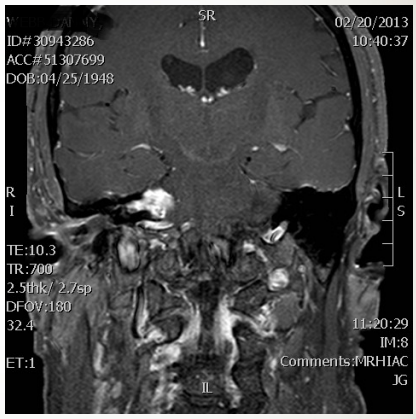
Unilateral Vestibular Lesion





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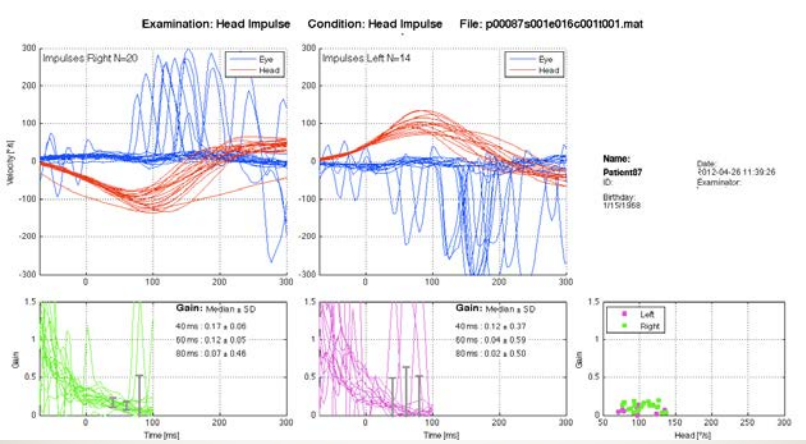
Abnormal vHIT



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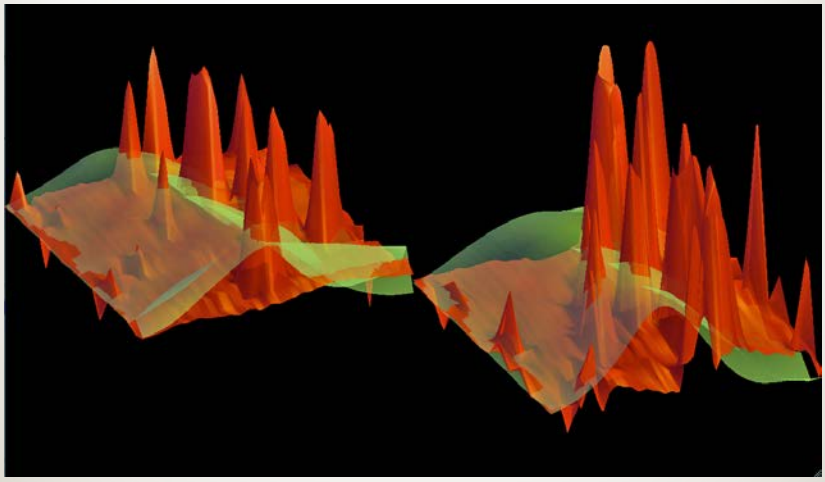

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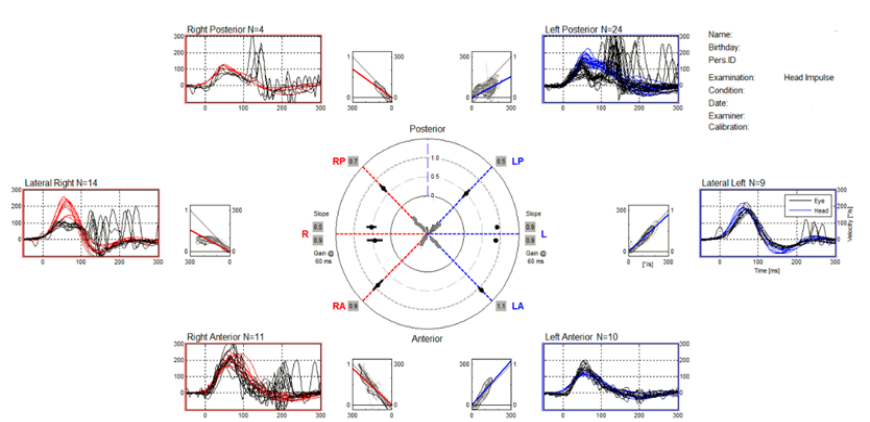
EyeSeeSix Final Report



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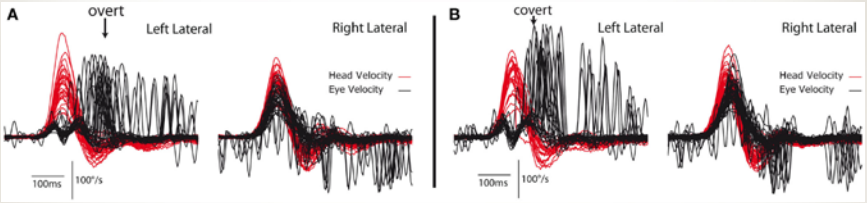
vHIT and Compensation



Initial head impulse test

Impulse test hours later

MacDougall & Curthoys. *Frontiers in Neuro-otology, 2012*

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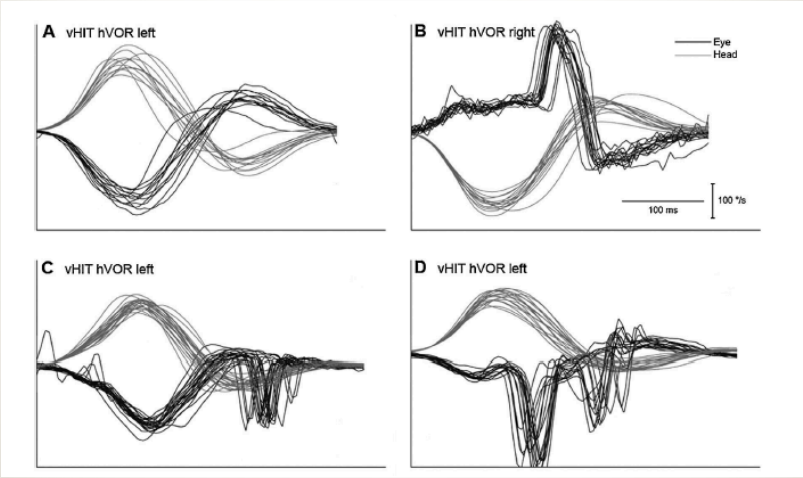
Variations of Responses



Blodow et al., Ausis Nasus Larynx, 2013

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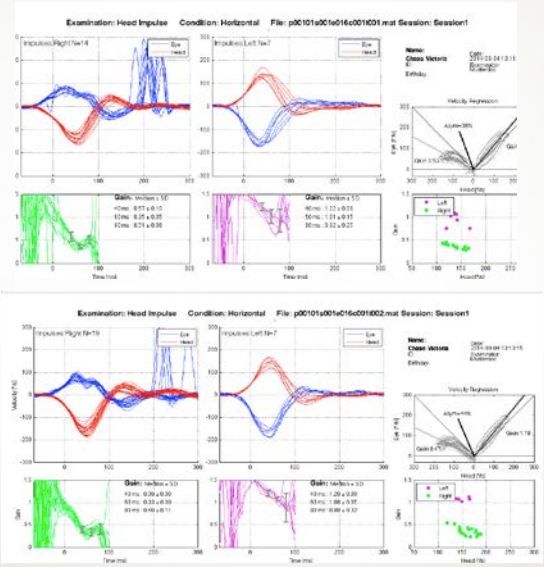
Absent Covert Saccades



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Clinical Application for Audiology

- We now have tools to assess low frequency (caloric) and high frequency function in the vestibular system.
- HIT testing and caloric testing can be different thus each provides unique information
- Good for bedside testing (e.g. inpatients)
- Well-tolerated
- Is relatively quick to do.

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vHIT and Peripheral Vestibular Impairments

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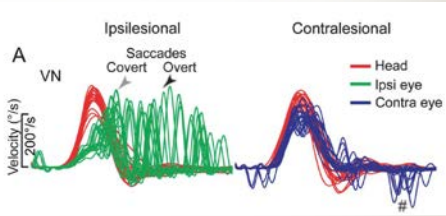
Vestibular Neuritis

- Ipsilesional gains were low.
- Contralesional gains were reduced by approximately 20%.



Chen et al., *Neurology*, 2014

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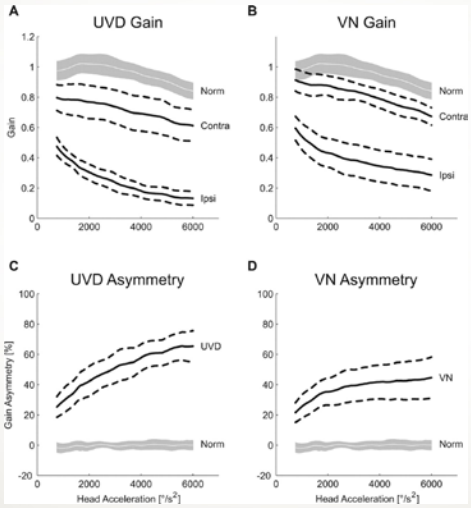
Gain and Impairment



Weber K P et al. Neurology 2008;70:454-463

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Recent Vanderbilt Study

Unilateral Peripheral Vestibular Impairments!

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Objectives

- To determine if a predictable relationship existed between self-reported dizziness handicap and vHIT.
- Describe the characteristics of vHIT ipsilesional and contralesional vestibulo-ocular reflex slow phase velocity in patients with varying levels of canal paresis.

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Objectives (con't)

- Determine the sensitivity and specificity of the vHIT for detecting horizontal semicircular canal impairment using the caloric test as the "gold standard."

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Design

- Subjects were 115 adults 65 years were included in the study (mean age 45.63 years [sd = 14.91], 58 males)presenting to a tertiary medical care center with symptoms of dizziness.
- Participants were administered a measure of self-report dizziness handicap (i.e. Dizziness Handicap Inventory DHI) and underwent caloric testing and vHIT at the same appointment.

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Design

- Extensive data cleaning was imposed to eliminate artifacts.
  - Blinks and miniblinks
  - Excessive oscillations (tracking system loses the pupil)
  - Delay responses or phase shifts
  - Multi-peak responses (examiner contacts goggles)
  - Head bounce
  - Responses that go in the wrong direction

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Design

- Caloric UW categories:
  - 0-26%
  - 26%-50%
  - 51%-75%
  - 76%-100%
- VOR responses from impulses with a velocity of less than 150 deg/sec were discarded.

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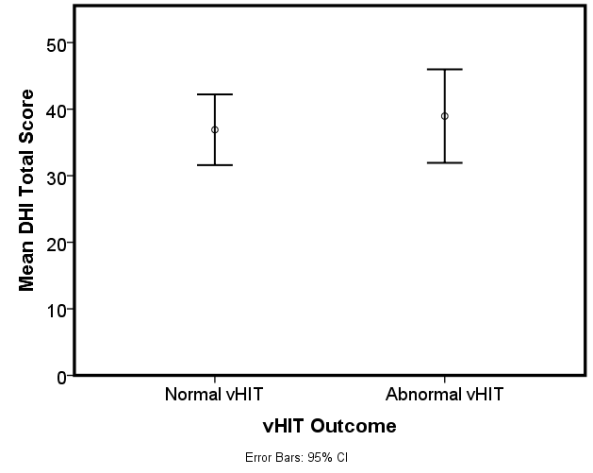
Mean DHI Total Score and vHIT Outcome



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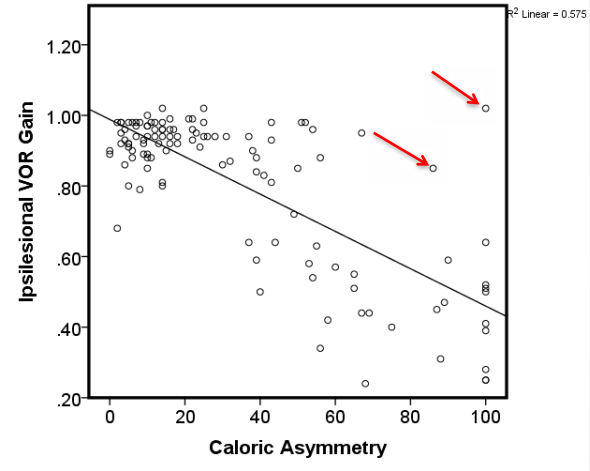
Ipsilesional VOR Gain and CA



(F = 50.51, df = 3, $p \leq 0.000$)

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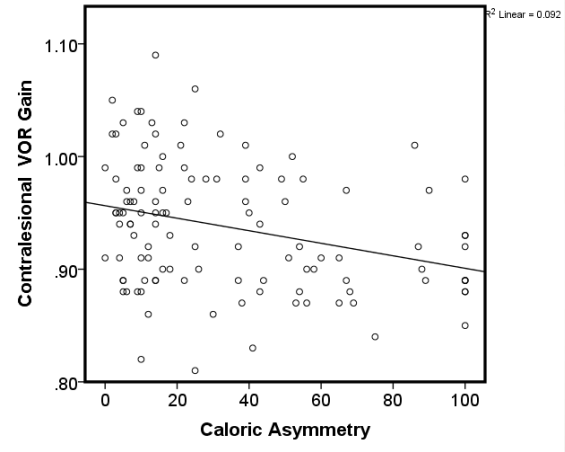
Contralesional VOR Gain and CA



(F = 4.097, df = 3, $p \leq 0.008$).

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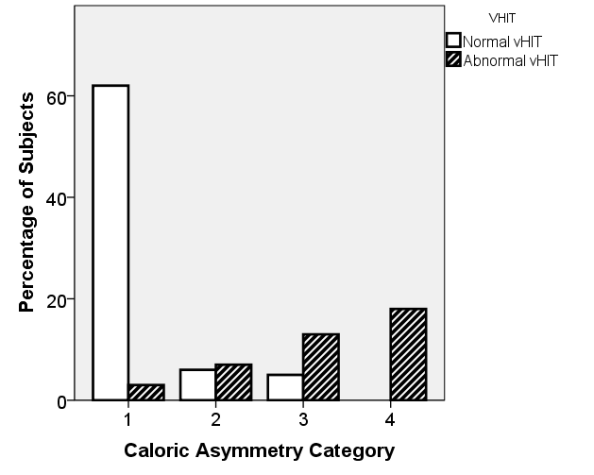
vHIT Outcome and Caloric Asymmetry Category



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Results-Peripheral Impairments

- A cut-off point of 39.50 percent caloric asymmetry optimized best sensitivity and specificity.
- Using a >39.5% caloric asymmetry as the normal upper limit the positive predictive value of the vHIT was 0.93 and the negative predictive value 0.85.

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Conclusions

- The level of self-reported dizziness handicap is not predicted by the outcome of the vHIT.
- vHIT and caloric data are not redundant
- Each test provides unique information regarding the functional integrity of the horizontal semicircular canal at different points on the frequency spectrum.

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Conclusions

- However, our data shows that a caloric asymmetry of 39.5% is required to optimize discrimination between an abnormal and normal vHIT in cases of unilateral peripheral impairment.
- It is our contention that the vHIT is a complementary test to the balance function examination and should viewed as such rather than as a replacement for caloric testing.

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Can Abnormal vHITs be Recorded in Patients with Central Impairments

YES!

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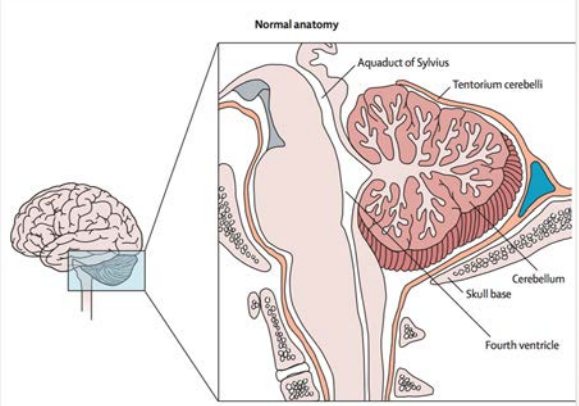
Posterior Fossa



Edlow et al., *Lancet Neurol,* 2008

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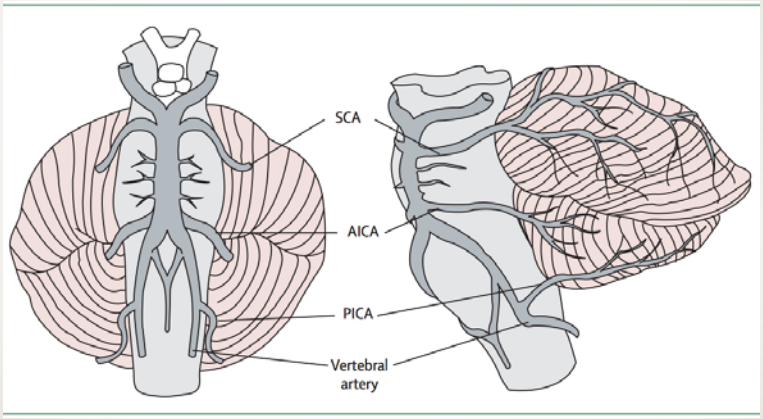
Posterior Circulation Stroke



Edlow et al., *Lancet Neurol,* 2008

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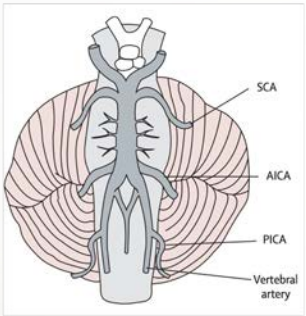
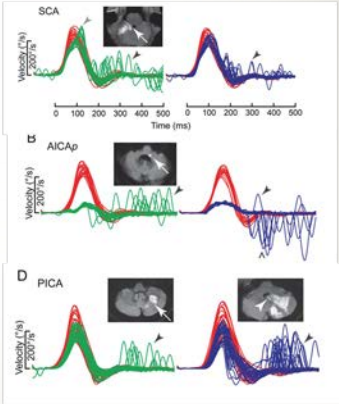
Abnormal vHIT Due to Posterior Circulation Strokes





Edlow et al., *Lancet Neurol,* 2008

Chen et al., *Neurology*, 2014

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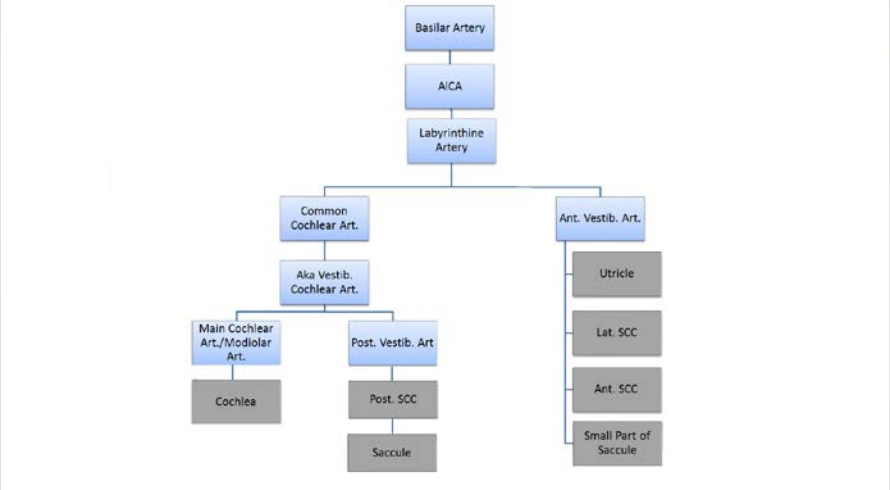

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Fact

- We still much we do not know all the patterns and ways in which the vHIT changes in different disorders and disease processes.
  - Cerebellar
  - Vestibular Nuclei
  - Peripheral
  - Disorders
    - Migraine
    - Meniere's
    - Vestibular neuritis

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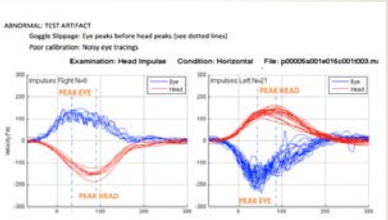
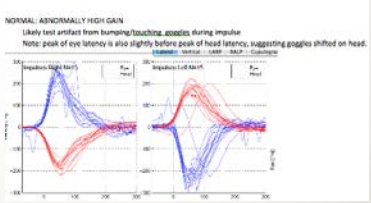
Challenges

- Blinks
- “Helping patient”
- Occasionally a test is not possible
- Training





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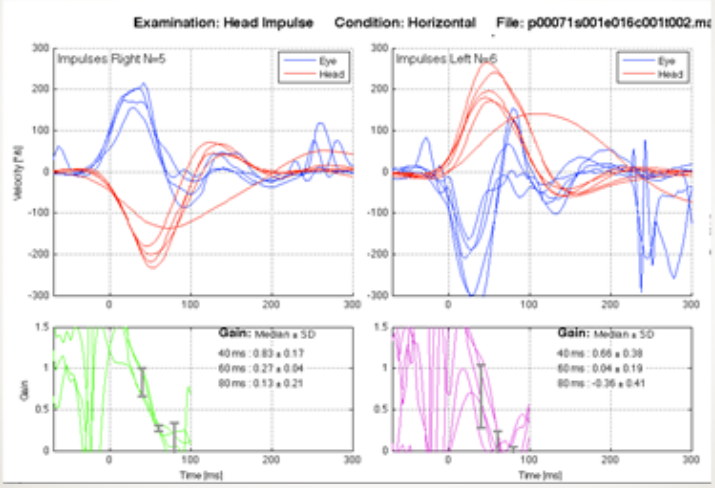
Patient Non-compliance



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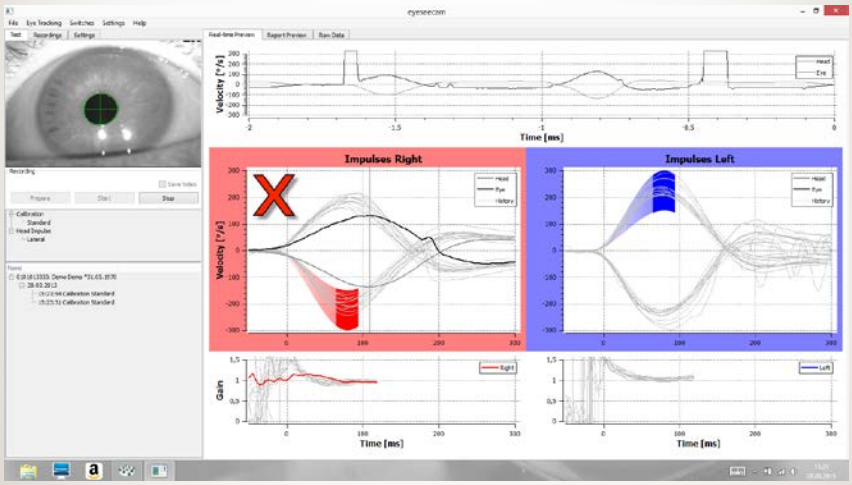
Low Head Velocity



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What is the HINTS exam

- Three step clinical decision rule:
  - Composed of three eye movement exams that have been suggested to be critical in differentiating peripheral from central impairments of acute continuous vertigo/dizziness (not transient-BPPV).
    - Head impulse
    - Nystagmus type
    - Test of skew

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HINTS

- HINTS:
  - Head Impulse
  - Nystagmus
  - Test of Skew
  - Hearing.
- 99% sensitivity
- 97% specificity for central vestibular disorders

Newman-Toker et al., *Acad Emerg Med*., 2013

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The HINTS Exam

- Is the HINTS exam (Head-Impulse—Nystagmus—Test-of-Skew)
- A negative HINTS examination has been suggested to be able to rule out a stroke better than a negative MRI with DWI in the first 24 to 48 hours after symptom onset with a specificity of 96%.

Newman-Toker et al., *Acad Emerg Med*., 2013

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Pediatric

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Meniere's Disease

vHIT and caloric results in Ménière's disease 1

Title: The dissociation of video head impulse (vHIT) and bithermal caloric test results provide topological localization of vestibular system impairment in patients with "definite" Ménière's disease.

McCaslin et al., 2014, *American Journal of Audiology*

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The dissociation of video head impulse (vHIT) and bithermal caloric test results provide topological localization of vestibular system impairment in patients with definite Ménière's disease.

McCaslin et al., 2014 in press.

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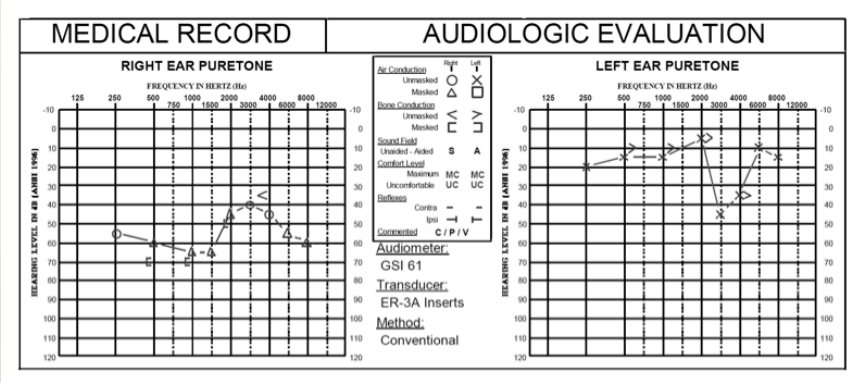
Audiometry



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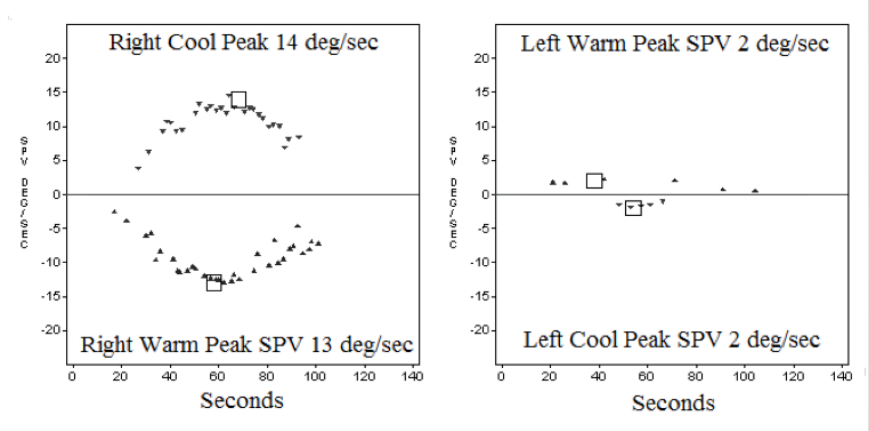
Abnormal Caloric Response



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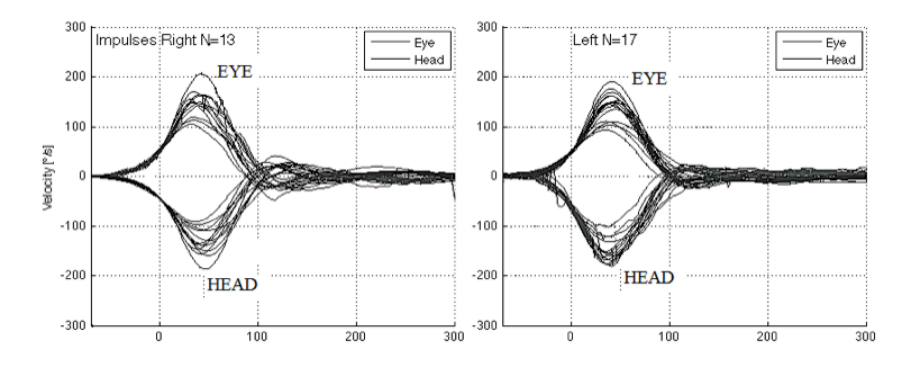
vHIT



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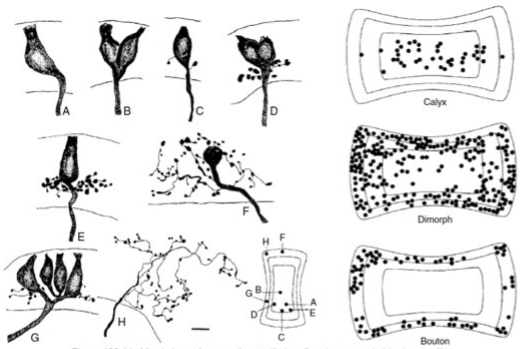

Figure 139-11. Morphology of mammalian vestibular afferents as revealed by horseradish peroxidase labeling of individual units in the chinchilla. **A,** Calyx fiber innervating a single type I hair cell. **B,** Calyx fiber innervating two Type I hair cells. **C** through **G,** Dimorphic fibers innervate both Type I and II hair cells. H, Bouton fiber. Inset: Locations of these afferents are placed on a standard map of the crista. *Right,* Three standard maps of the cristae divided into concentrically arranged central, intermediate, and peripheral zones of equal areas. Shown are the locations of calyx, dimorphic, and bouton fibers with each symbol (●) representing a single dye-filled fiber. Dimorphic units make up 70% of the population, bouton units 20%, and calyx units 10%. From Fernandez, Baird, and Goldberg.[38]

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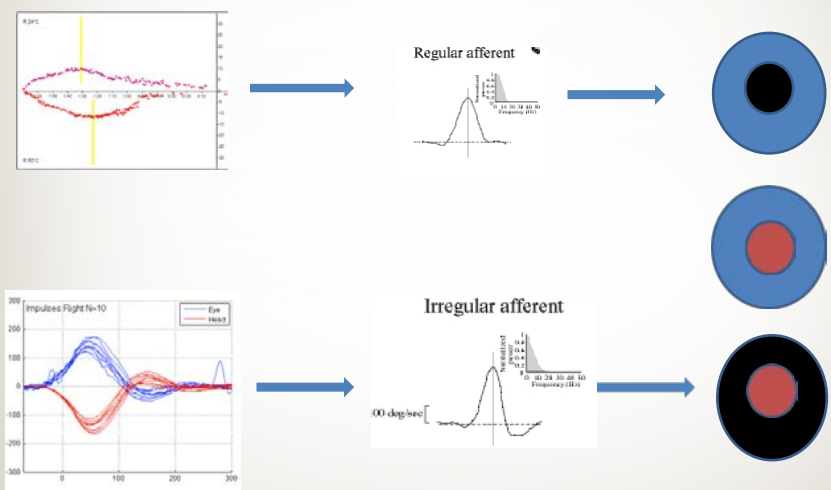
vHIT in Meniere's Syndrome



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Current vHIT Studies

- Auditory Neuropathy
- Enlarged Vestibular Aqueduct
- Meniere's vs. Migraine
- Monitoring pediatric Hem/onc patients

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Questions