Role of Vestibular Tests in Diagnosis of Dizziness

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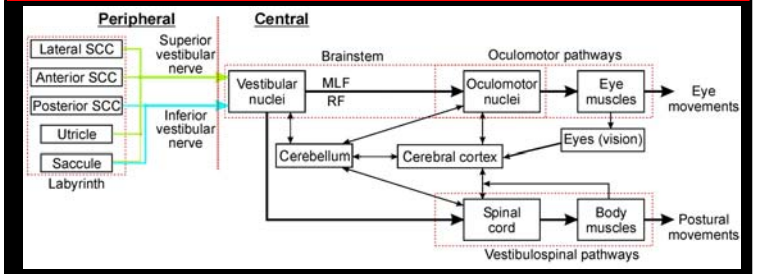
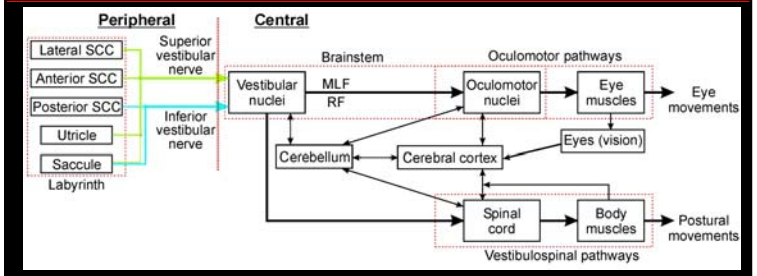
Anatomical Sites and Causes of Dizziness



- ICD-9 codes with primary complaint of dizziness ~63
  Source: A Guide to Evaluation and Management of Dizziness (2001), *ICS Medical*
  - Anatomical sites – ear, brain, eyes, muscles/joints, other
  - Underlying causes – infection, vascular, psychogenic, trauma, metabolic, tumors, neoplasms, toxic, congenital

Rationale for Vestibular Function Tests

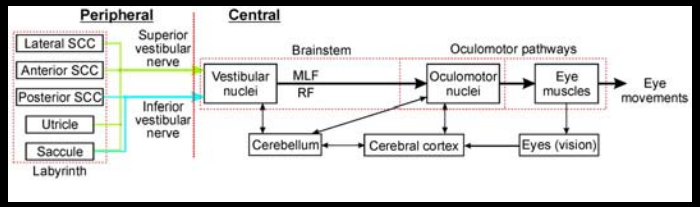


- No direct access to the labyrinth or vestibular nerve
- Must rely on secondary motor responses
  - Postural movements (vestibulo-spinal reflex)
  - Eye movements (vestibulo-ocular reflex)

Role of VNG/ENG In Clinical Decision-Making

- Support diagnosis
  - Document unilateral/bilateral loss of vestibular function
  - Confirm BPPV
  - Detect central lesions that are missed during routine physical exam
- Decide if additional tests (e.g., MRI) are needed
- Preoperative evaluation
  - Acoustic neuroma/ablative procedure/cochlear implants
- Detects abnormalities in ~50% of dizzy patients
  - Detection rates are as high as 75% for otologic diseases
  - Differentiate between peripheral and central lesions in about 80% of those with abnormal findings
  - Can identify side of lesion in about 75% of those with peripheral lesions
  - Does not rule out vestibular lesion
  - Rarely can identify the underlying cause (test of function)

Methods to Differentiate Peripheral vs Central Lesions



- Exhaustive search for central lesions
  - Oculomotor tests in ENG/VNG but currently, not able to identify every possible central lesion
- Subtracting out central pathways through repeated stimulations
  - Unilateral weakness in the caloric test (subject to caloric test limitations)
- Differentiate based on frequency/velocity/latency responses
  - Oculomotor responses are much slower than vestibular responses
  - Head impulse test and high-frequency active head rotation test

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VNG/ENG

Outline

- VNG/ENG test battery
  - Best practices in administering each test
  - Recognizing and avoiding common errors and artifacts
  - General interpretation guidelines for each test
  - Correlations among different tests

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VNG/ENG Pre-test Protocol

- Patient interview and chart review
  - To obtain clinical information and modify test procedures when necessary
- Otoscopic ear examination
  - To remove cerumen when necessary
- Eye movement examination
  - To modify recording method (electrode arrangement in ENG or camera configuration in VNG) when necessary
- Application of electrodes in ENG
  - To allow time for electrodes to settle
- Placement of goggles in VNG
- Electrode testing in ENG or video adjustment in VNG
- Calibration of eye movements

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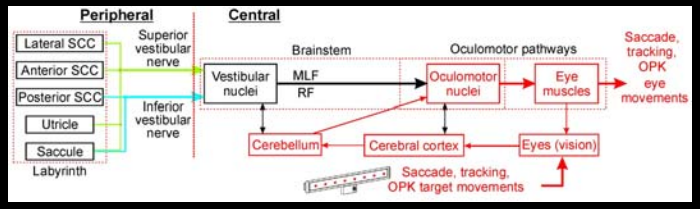
Oculomotor Tests

Best Practices in Oculomotor Tests

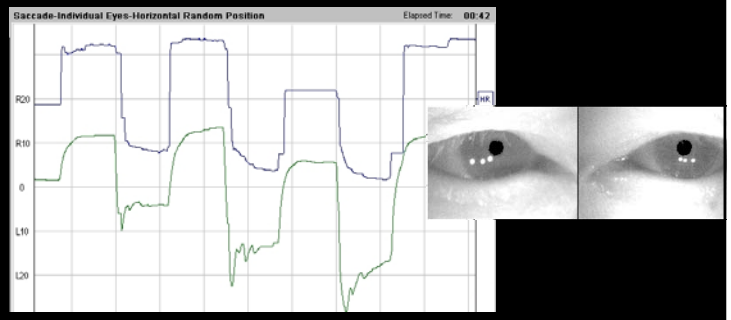
- Ask the patient to avoid head movements
- Ask the patient not to anticipate target movements
- Run the test as long as necessary to collect enough data
- Look for the patient's best performance (repeat tests when necessary as true abnormalities are consistent and repeatable)
- Artifacts: watch for head movements, target anticipation, and calibration errors

Interpretation of Oculomotor Tests



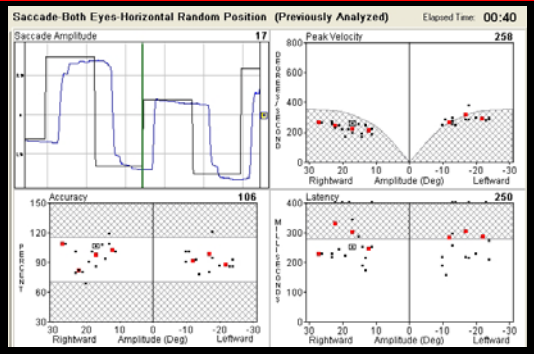
- Tests of oculomotor function (with fixation)
  - Saccade (fast eye movements)
  - Tracking (slow voluntary/smooth pursuit eye movements)
  - Optokinetic (reflexive eye movements but the test performed as a part of ENG/VNG is not a true test of optokinetic pathways regardless of the type of visual stimulus used)
  - With very few exceptions, abnormalities in the oculomotor tests indicate a central finding

Abnormal Saccades – *Internuclear Ophthalmoplegia*



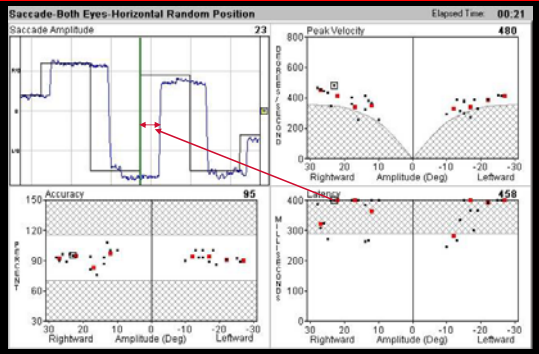
- *Internuclear Ophthalmoplegia* denotes a central lesion in the medial longitudinal fasciculus on the side of sluggish adduction
  - Record from both eyes independently

Abnormal Saccades - *Saccadic Slowing*



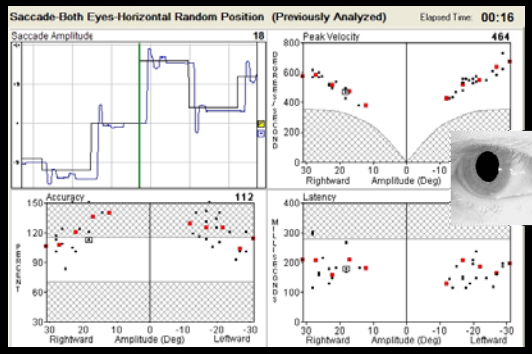
- *Saccadic slowing* denotes a central lesion in the basal ganglia, brain stem, cerebellum, peripheral oculomotor nerves or muscles (typically in diffuse lesions of the central pathways associated with neurodegenerative diseases)
  - May be due to fatigue, drowsiness, or medication (reversible)

Abnormal Saccades – *Delayed*



- *Delayed saccades* (latencies >> 200 msec) denote a central lesion in the frontal/frontoparietal cortex or basal ganglia (interpret conservatively)
  - Low clinical value if bilateral (more significant if unilateral)
  - May be caused by inattention, poor visual acuity, and medication

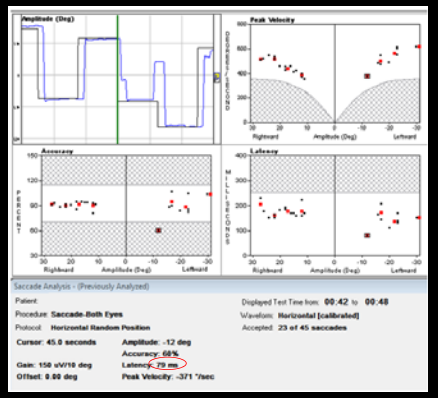
Abnormal Saccades - *Dysmetria*



Hypermetria

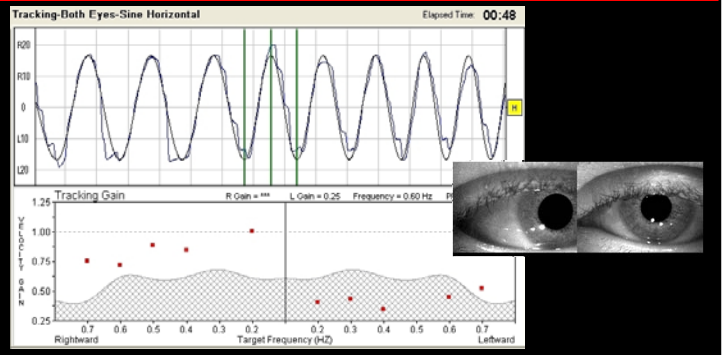
- *Saccadic dysmetria* denotes a central lesion in the cerebellar flocculus (hypometria) or the cerebellar vermis (hypermetria)

Saccade Test – *Anticipating Target Movements*



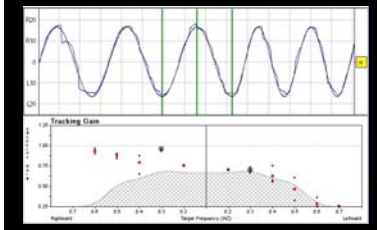
- Patient is anticipating target movements (latency << 200 msec)
  - Also watch for head movements and calibration errors

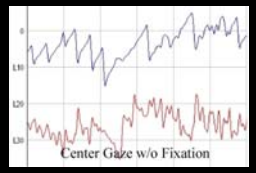
Abnormal Tracking - *Unilateral Defective Pursuit*



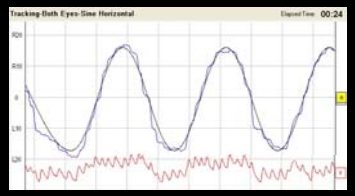
- *Defective tracking* (pursuit) denotes a central lesion. If symmetric – diffuse cortical, basal ganglia, or cerebellar diseases. If asymmetric – focal lesions involving ipsilateral cerebellar hemisphere, brain stem, or parieto-occipital region.

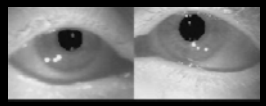
Effect of Superimposed Nystagmus on Tracking



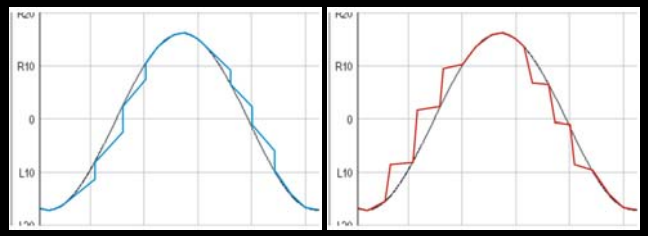


- Borderline unilateral defective tracking caused by strong spontaneous nystagmus (in the direction of fast phases)
  - Effect of superimposed nystagmus and not abnormal tracking





Oculomotor Tests – *Anticipating Target Movements*



Abnormal Anticipating

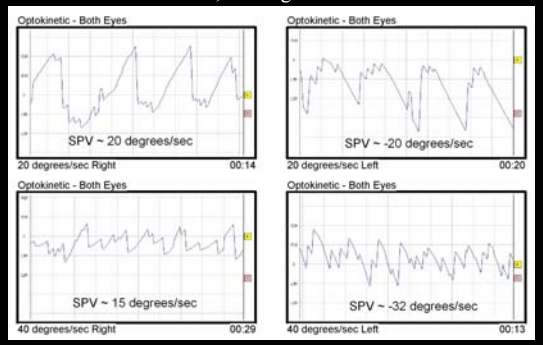
- Watch for patient anticipating (getting ahead of) target movements
  - Also watch for head movements and calibration errors

Correlations in Oculomotor Tests – *Tracking & OPK*

- Since tracking and OPK findings are often overlapping, do they share the same central pathways?
  - True OPK originates from retinal stimulation (requires full-field visual stimulation) and is a reflexive response
  - Tracking originates from foveal stimulation (requires a small target) and is a voluntary response
  - When the stimulus is a small target (as in a light bar), both tracking and OPK tests evaluate the same central pathways
  - Full-field visual stimulation does not guarantee true OPK responses because both tracking (foveal) and OPK (retinal) receptors are stimulated
  - True OPK testing requires removing foveal responses (optokinetic after-nystagmus test)

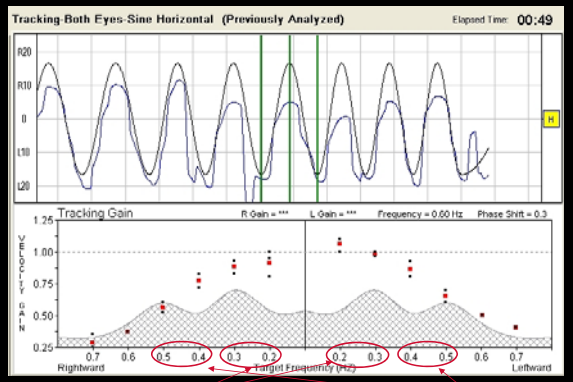
Correlations in Oculomotor Tests – *Tracking & OPK*

- OPK and tracking test results should be identical *when* equivalent test parameters are used and if age effects are considered
  - In case of conflict, investigate more



Reduced OPK nystagmus intensity for high-velocity rightward target movements

Correlations in Oculomotor Tests – *Tracking & OPK*



~ 20°/sec OPK

~ 40°/sec OPK

Gaze Stabilization Tests

Best Practices in Gaze Stabilization Tests

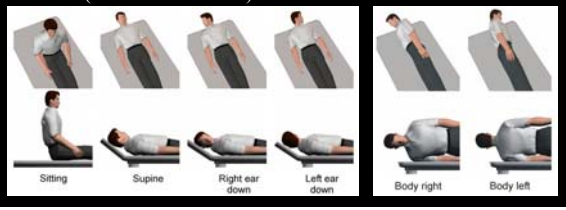
- Purpose – to examine the patient's ability to maintain steady gaze in different conditions (most common manifestation of gaze instability is nystagmus)
  - Gaze test – gaze stability in different off-center gaze positions
  - Spontaneous nystagmus test – gaze stability in the absence of vestibular stimulation with and without visual stimulation
  - Static position test – gaze stability in different head positions
- Any nystagmus in gaze stabilization tests will be present in other parts of VNG/ENG that are performed under similar conditions
  - Nystagmus in gaze test with fixation → oculomotor tests
  - Nystagmus in supine position without fixation → caloric test

Best Practices in Gaze Stabilization Tests

- Gaze Test
  - Record eye movements as the patient fixates on targets at 25-30° rightward, 25-30° leftward, 25-30° upward, and 25-30° downward
  - In each gaze position, record for as long as necessary to make a definite decision (at least 20 seconds)
  - If nystagmus or other abnormalities are observed in any gaze position, return to that position and reexamine
  - Results must match visual exam results
- Spontaneous nystagmus test
  - Record eye movements in center gaze both with and without fixation (alert the patient when testing without fixation)
  - For each condition, record for as long as necessary to make a definite decision (at least 20 seconds)

Best Practices in Gaze Stabilization Tests

- Static position test
  - Record eye movements with and without fixation as the patient holds different head positions (at least 4 head positions)
    - If nystagmus appears when head is turned to right or left, check the effect of neck rotation by turning the body to right or left
    - Some laboratories include other positions such as head hanging
    - Include any head position when patient has specific complaints
  - Alert the patient when testing without fixation
  - In each head position, record as long as necessary to make a definite decision (at least 20 seconds)



Gaze Stabilization Tests – *Streamlined Procedure*

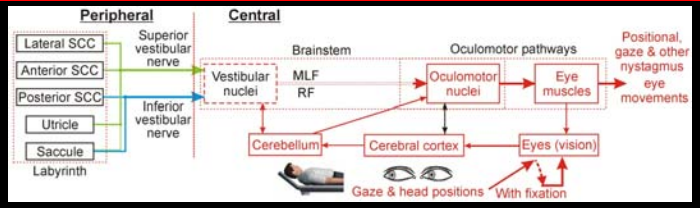
- Gaze test
  - Record eye movements as described before in right, left, up, down, and center gaze positions with fixation only
- Static position test
  - Record eye movements as described before in different head positions without fixation only
- Spontaneous nystagmus test
  - No need for a separate test because the information can be extracted from the gaze test in center gaze with fixation and the static position test in sitting position without fixation

Other combinations of with and without fixation positions not included in the streamlined procedure usually do not provide additional diagnostic information

General Interpretation of Gaze Stabilization Tests

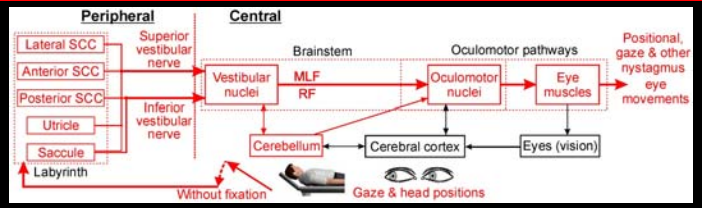
- The following information is needed for interpretation:
  - Presence of nystagmus in any gaze/head positions
  - Direction of nystagmus in any gaze/head positions
  - Intensity of nystagmus in any gaze/head positions (primarily for tests without fixation)
  - Effect of fixation on the presence or intensity of nystagmus

Interpretation of Gaze Stabilization Tests



- Abnormalities in the gaze test with fixation usually indicate a central finding
  - One exception is the "leak-through" (incompletely suppressed) strong spontaneous nystagmus without fixation

Interpretation of Gaze Stabilization Tests

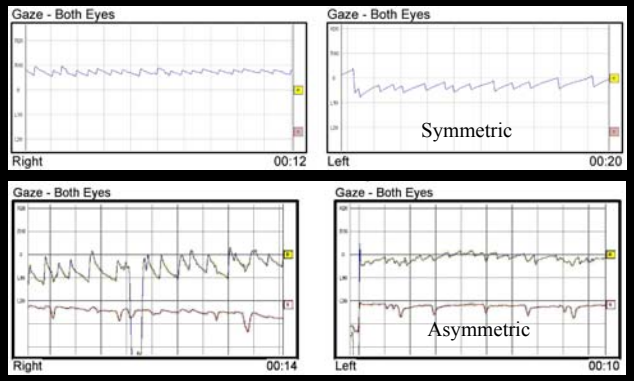


- Abnormalities in tests of gaze stabilization without fixation (spontaneous nystagmus and static position tests) are typically non-localizing
  - Can support localizing findings in other vestibular tests

General Interpretation of Gaze Stabilization Tests

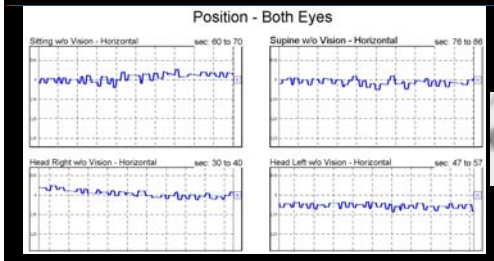
- For horizontal nystagmus:
  - Changes direction in a single gaze position → Central
  - Is present with fixation and its intensity does not increase significantly (at least doubles) without fixation → Central
  - Is present without fixation and its intensity is less than a threshold (6°/sec in ENG, 4°/sec in VNG) → Not significant
  - All other forms of horizontal nystagmus → Non-localizing
- For vertical nystagmus:
  - Is present with fixation → Central
  - Is present without fixation and its intensity is less than a threshold (7°/sec in VNG) → Not significant
  - All other forms of vertical nystagmus → Unknown clinical significance

Abnormal Gaze – *Gaze-Evoked Nystagmus*

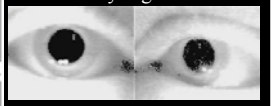


- *Gaze-evoked nystagmus* denotes a central lesion in the cerebellum or brain stem (common in lesions of cerebellar flocculus)

Abnormal Gaze Stabilization – *Saccadic Intrusion*



Square wave jerk nystagmus



- Normal limits
  - Abnormal only when present with fixation
  - Estimates of normal limits for amplitude, frequency, age dependency, etc. vary due to differences in recording methods (frequency increases with age)
- Localization
  - *Square wave jerk nystagmus* denotes a central lesion in the cerebellum or basal ganglia.

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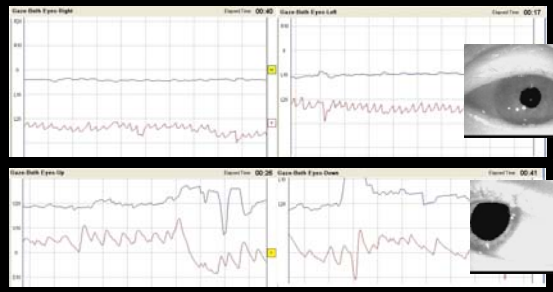
Abnormal Gaze Stabilization – *Vertical Nystagmus*



Downbeat nystagmus

Upbeat nystagmus

- *Downbeat or upbeat gaze nystagmus* with fixation denotes a central lesion in the cerebellum or underlying medulla
  - Upbeat nystagmus is more commonly associated with side effects of medications, nicotine, or alcohol
- *Vertical nystagmus without fixation* that exceeds the normal limit (7°/sec) denotes a finding of unknown clinical significance

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Abnormalities in the Gaze Stabilization Tests

- Vestibular (spontaneous) nystagmus
  - Horizontal with or without torsional component or vertical with torsional component (in lesions involving vertical canals)
  - Horizontal and vertical components suppressed with fixation
    - Intensity decreases by at least 50%
  - Intensity may vary due to gaze position and alertness level
    - Stronger when gaze directed toward fast phases
  - Direction may vary in different head positions but not in different gaze positions
  - In the absence of fixation, abnormal only if intensity is greater than a threshold (all forms including geotropic and ageotropic)
    - Horizontal – 6°/sec in ENG, 4°/sec in VNG
    - Vertical – 7°/sec in VNG (upbeat more common in normal individuals)

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BITHERMAL CALORIC TEST

Caloric Test – *Rationale*

- Purpose – To compare responses from the right and left labyrinths to caloric stimuli
- Complicated and time-consuming, but the most important part of VNG/ENG
- Most useful in detecting unilateral vestibular abnormalities
  - Allows independent assessment of responses from right and left labyrinths (lateral semicircular canals) to caloric irrigation of the external auditory canal
  - Not as effective in assessing absolute vestibular responses
    - Intensity of nystagmus in response to individual irrigations depends on heat transfer issues and does not usually provide diagnostic information (except for hypo- and hyper-activity)

Caloric Test – *Assumptions*

- Most common method is bithermal calorics (each ear is irrigated twice to elicit both excitatory and inhibitory responses)
- Basic assumption of caloric testing is that right and left ears receive equal stimulation
  - Controllable – temperature, volume, duration, alerting, cerumen
  - Uncontrolled – ear anatomy, middle ear anomalies, perforations, body temperature (may affect individual irrigations but not the overall interpretation)

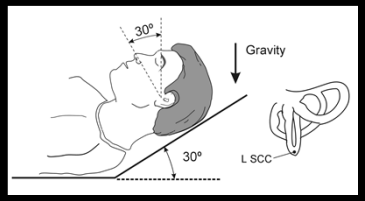
Caloric Test – *Common Irrigation Parameters*

	Water	Air	Closed-Loop
Volume	250 ml	8 liters	-
Duration	30 sec	1 min	45 sec
Temperatures	44º/30º $\pm$7ºC	50º/24º $\pm$13ºC	46º/28º $\pm$9ºC

- When used appropriately, all three irrigator types can produce acceptable caloric responses with similar test-retest reliability
- Normative values for some response parameters may have to be adjusted if different irrigation values are used

Caloric Test – *Procedure*

- Place patient in the standard caloric position (supine with head flexed forward 30°)



Places the lateral canal in the vertical plane

- In this position, warm irrigations cause excitatory responses and cold irrigations cause inhibitory responses
  - Nystagmus follows COWS rule

Caloric Test – *Practical Issues*

- Calibration between irrigations
  - ANSI recommendation to recalibrate between irrigations is based on non-computerized/strip chart recording (BSA has reversed earlier position)
  - In computerized ENG and VNG, verify calibration (using mock saccade/tracking test) and recalibrate only if necessary
- Order of Irrigations
  - Start with one temperature and irrigate ears in the same order for each temperature (ANSI/BSA both recommend starting with warm)
    - Starting with cool irrigations may reduce the typical difference between warm and cool responses (Noaksson et al, 1998)
- Wait period between irrigations
  - ANSI recommendation to wait a fixed period between start of consecutive irrigations does not differentiate between strong and weak responses (BSA recommends a minimum of 7 minutes between start of consecutive irrigations)
  - Wait a fixed period of time (3-5 minutes) after the previous caloric nystagmus ends before starting the next irrigation

Caloric Test – *Practical Issues*

- ANSI recommendation to disallow air is based on outdated studies
  - Ratio of air to water irrigator sales – 4 to 1
  - Currently, closed-loop water irrigators are no longer manufactured/supported
  - Continue using air irrigators but remember that air is technically more challenging and requires a longer learning period
- How many tests for fixation suppression?
  - One for each nystagmus direction but do four and choose two irrigations where nystagmus intensities just before fixation are approximately equal
- Are two irrigations (cool or warm) enough?
  - Significantly increases chance of identifying caloric results as abnormal when they are not (false positive)
  - Can be used as a screening test for normal calorics if these conditions are met:
    - No oculomotor abnormalities
    - No gaze/spontaneous nystagmus
    - Less than 10% of right-left asymmetry for warm irrigations

Caloric Test – *Other Practical Issues*

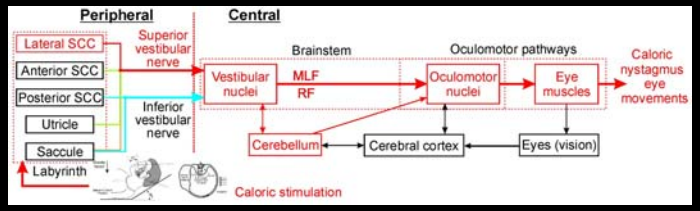
- How to reduce chances of the patient becoming sick?
  - Interrupt the irrigation if nystagmus intensity exceeds a critical limit. Use the same time period for other irrigations
- What about caloric-induced vertical nystagmus?
  - Caloric induced vertical nystagmus is present in normal individuals and patients with various disorders
  - Most likely due to stimulation of posterior/anterior canals
  - Caloric perversion
    - All four irrigations must generate purely vertical nystagmus or,
    - Vertical nystagmus must be much stronger than horizontal nystagmus
    - Central finding but extremely rare (consider other options first, e.g., crosstalk)
- Is there an age limit for caloric testing?
  - No upper limit but watch for poor irrigations in older patients
  - Lower limit of ~6 years of developmental age for children and developmentally delayed adults

Caloric Test - *Abnormal Values*

- BW - responses from both right and left ear < 12°/sec (Total RE < 12°/sec and Total LE < 12°/sec)
  - Alternative values based on total caloric responses or based on individual irrigations are used by some laboratories
- |UW %| > 25% (alternatives 20% - 30%)
- |DP % | > 30% (alternatives 25% - 50%)
  - |Baseline shift|> 6º/sec (4º/sec for VNG)
  - |GA %| > 25% but is not established
- FI % > 60% (alternatives 50% - 60%)
- Hyperactive – Total RE > 140°/sec or Total LE > 140°/sec

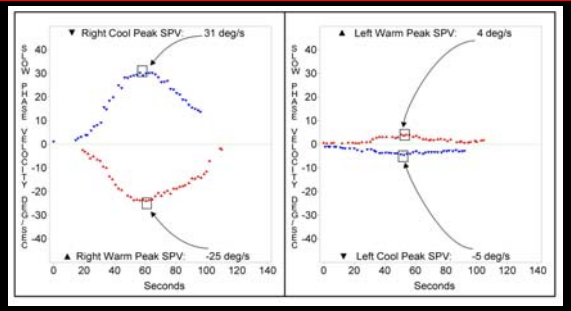
Normative values for BW and hyperactivity may be affected if different irrigation parameters are used but other values are not as sensitive to moderate variations of those parameters.

Interpretation of Caloric Test



- Test of lateral canals and the superior portion of vestibular nerve
  - Unilateral weakness (canal paresis) indicates a peripheral vestibular lesion involving the lateral (horizontal) canal or its afferent pathways on the side of the weaker response
  - In the acute phase, significant spontaneous nystagmus is present
  - Can be caused by diseases that affect the labyrinth, the vestibular nerve, or the blood supply to those sites
  - Other abnormalities are either non-localizing (directional preponderance or bilateral hyporesponsive) or central (hyperresponsive or failure of fixation suppression) findings

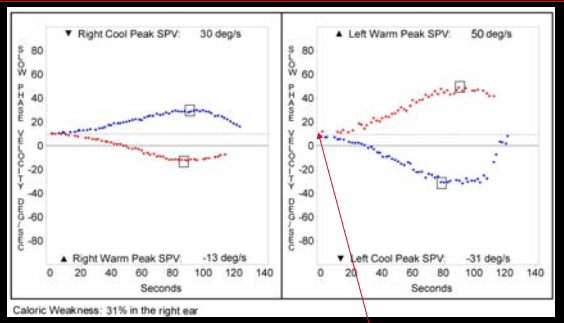
Abnormal Calorics – *Unilateral Weakness*



Total RE = RC - RW = 56°/sec Total LE = LW - LC = 9°/sec

UW% = (56-9)/(56+9)*100 = 72% in the left ear

Abnormal Calorics – *Unilateral Weakness*



Leftbeating nystagmus without fixation should be seen in the supine position (~10°/sec)

Abnormal Calorics – *Unilateral Weakness*

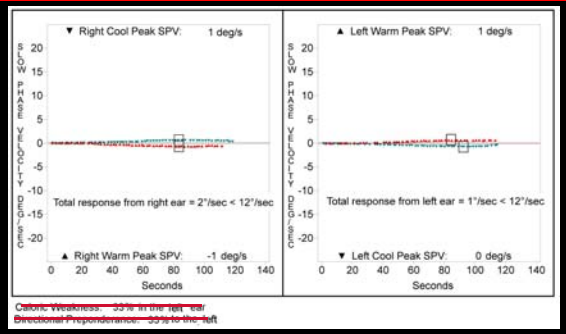
- Criterion for abnormality
  - UW % > 25% (range 20% - 30 %)
- Localization
  - [*Unilateral weakness* denotes a peripheral vestibular lesion involving the lateral (horizontal) semicircular canal or its afferent pathways on the side of the weaker response] (the involved pathway extends from the end-organ to the root entry zone of the vestibular nerve in the brain stem)

Abnormal Calorics – *Unilateral Weakness*

- Diseases that affect the labyrinth or the vestibular nerve (from the end-organ to the root entry zone in the brain stem) or the blood supply to those sites can cause unilateral vestibular lesion
- Acute
  - Viral/bacterial labyrinthitis (acute stage)
  - Vestibular neuritis (acute stage)
  - Meniere's disease (initial episodes)
  - Labyrinthine concussion
  - Labyrinthine infarction
- Chronic
  - Viral/bacterial labyrinthitis (chronic stage)
  - Vestibular neuritis (chronic stage)
  - Meniere's disease (advanced stage)
  - Vestibular schwannoma/ acoustic neuroma

Central lesions that affect the root entry zone of the vestibular nerve (e.g., M.S.) can cause unilateral weakness but other CNS signs will be present

Abnormal Calorics – *Bilateral Weakness*

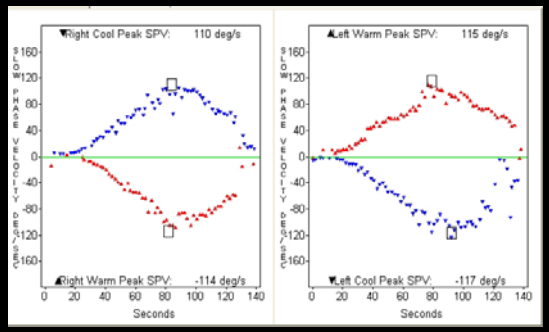


When bilateral caloric weakness is present, an additional test (head impulse, rotation chair, active head rotation, or bilateral ice water) is needed to determine if true bilateral vestibular lesion or hyporesponsiveness exists.

Abnormal Calorics – *Hyporesponsiveness (BW)*

- Criterion for abnormality
  - Total RE < 12°/sec and Total LE < 12°/sec
- Localization
  - [*Hyporesponsiveness (BW)* denotes either peripheral vestibular lesion in both ears or a central lesion]
- Etiologies
  - Idiopathic
  - Ototoxicity
  - Bilateral Meniere's disease
  - Congenital malformations
  - Cerebellar degeneration and tumors

Abnormal Calorics – *Hyperresponsiveness*



Total RE = RC - RW = 224°/sec Total LE = LW - LC = 232°/sec

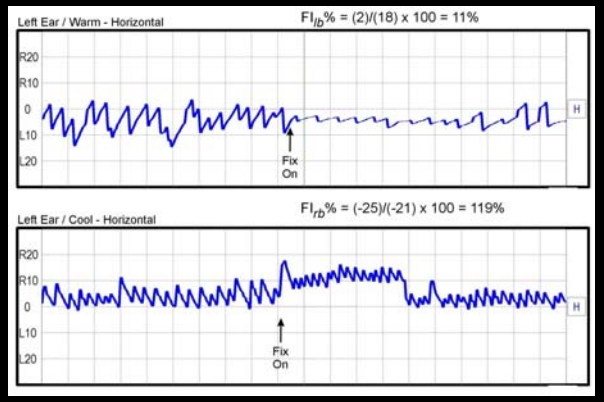
Rule out *tympanic membrane perforation* and *overcalibration*

Abnormal Calorics – *Hyperresponsiveness*

- Criterion for abnormality
  - Total RE > 140°/sec or Total LE > 140°/sec
- Localization
  - [*Hyperresponsiveness* denotes a central lesion] (most likely due to loss of inhibitory responses at the vestibular nuclei)
- Etiologies
  - Cerebellar atrophy and diseases affecting the cerebellum (also reported in patients with migraine and motion sensitivity syndrome)

Abnormal Calorics – *Failure of Fixation Suppression*

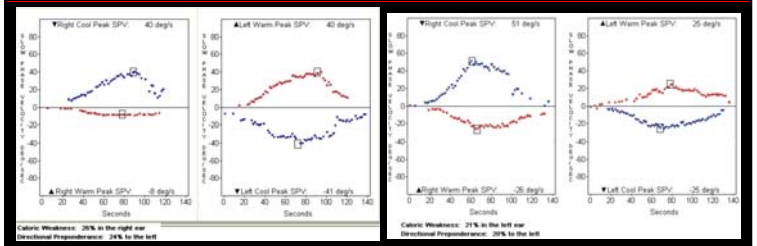
$FI\% = SPV_{Fix} / SPV_{NoFix} \times 100$



Abnormal Calorics – *Failure of Fixation Suppression*

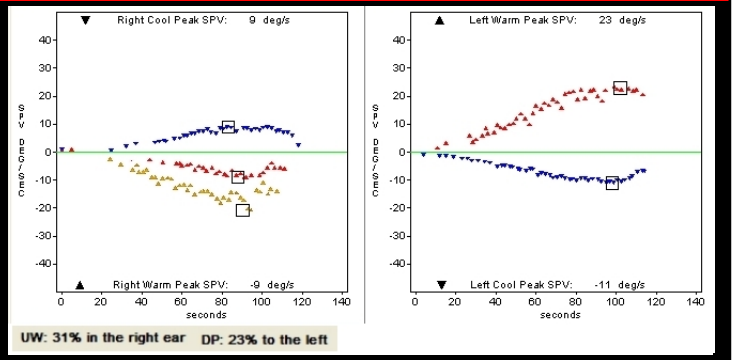
- Criterion for abnormality
  - FI% > 60% (range 50% - 60%)
- Localization
  - [*Failure of fixation suppression* denotes a central lesion] involving parietal-occipital cortex, pons, or cerebellum (most prominent in lesions involving midline cerebellum)
  - Patients with impaired fixation suppression usually have abnormal tracking

Caloric Test – *Artifacts*



One irrigation produces significantly different response (dominates the test result). Repeat?

Caloric Test – *Pitfalls*



Temperature effect. Does not affect UW and DP measures unless there is another technical error. Repeat?

Role of VNG/ENG In Clinical Decision-Making

- Support diagnosis
  - Document unilateral/bilateral loss of vestibular function
  - Confirm BPPV
  - Detect central lesions that are missed during routine physical exam
- Decide if additional tests (e.g., MRI) are needed
- Preoperative evaluation
  - Acoustic neuroma/ablative procedure/cochlear implants
- Detects abnormalities in ~50% of dizzy patients, many localizing
  - Detection rates are as high as 75% for otologic diseases
- Does not rule out vestibular lesion
- VNG/ENG tests of function - Rarely identifies underlying disease
  - Must be used along with history, physical exam, and other tests to make diagnosis