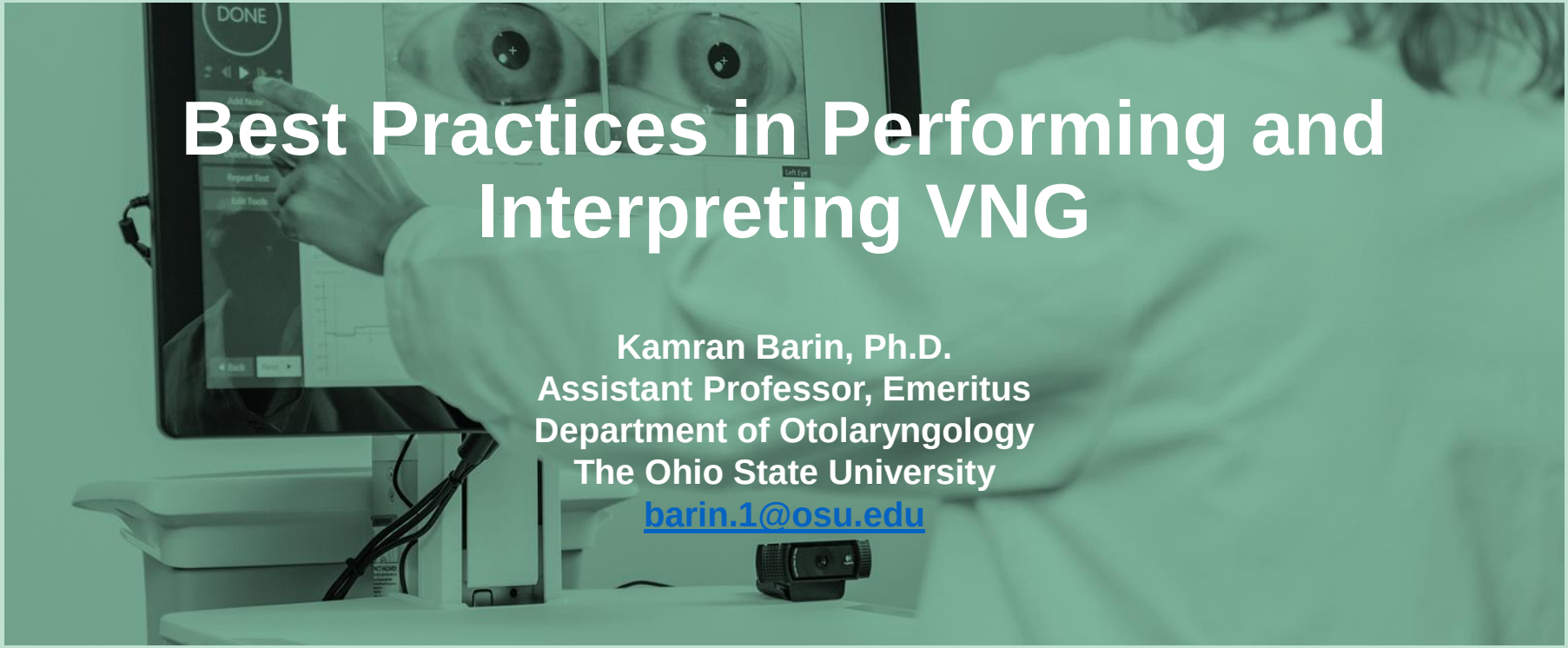

Best Practices in Performing and Interpreting VNG

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Outline

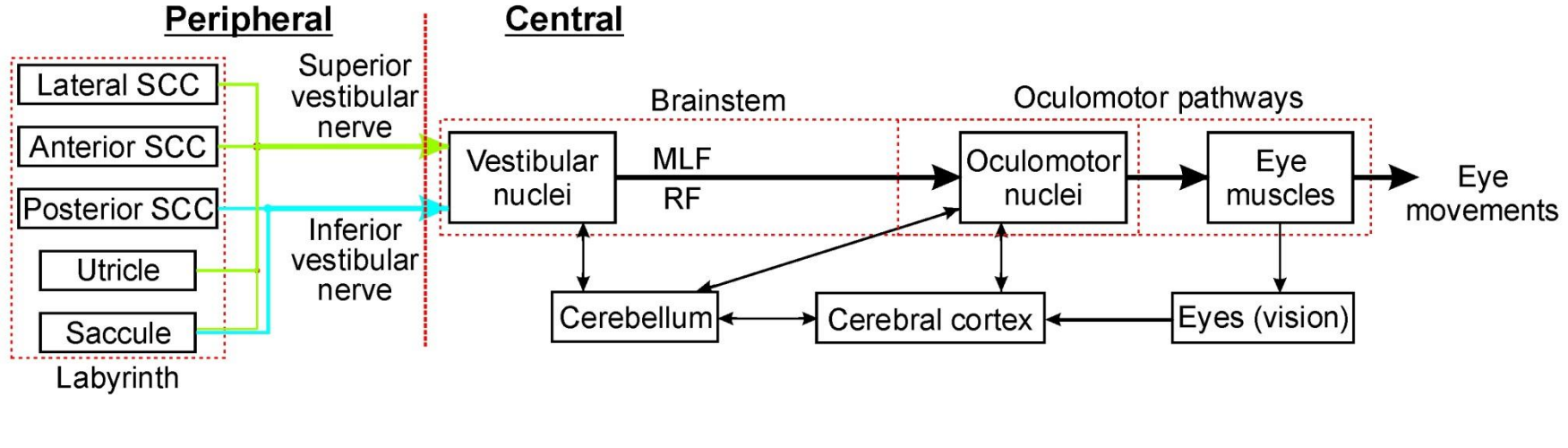
- VNG/ENG test battery
  - Best practices in administering each test
    - Oculomotor and gain stabilization tests
    - Caloric and dynamic positioning tests
  - Recognizing and avoiding common errors and artifacts
  - General interpretation guidelines for each test
  - Clinical application

Best Practices in VNG/ENG

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

Overview of VNG/ENG Subtests



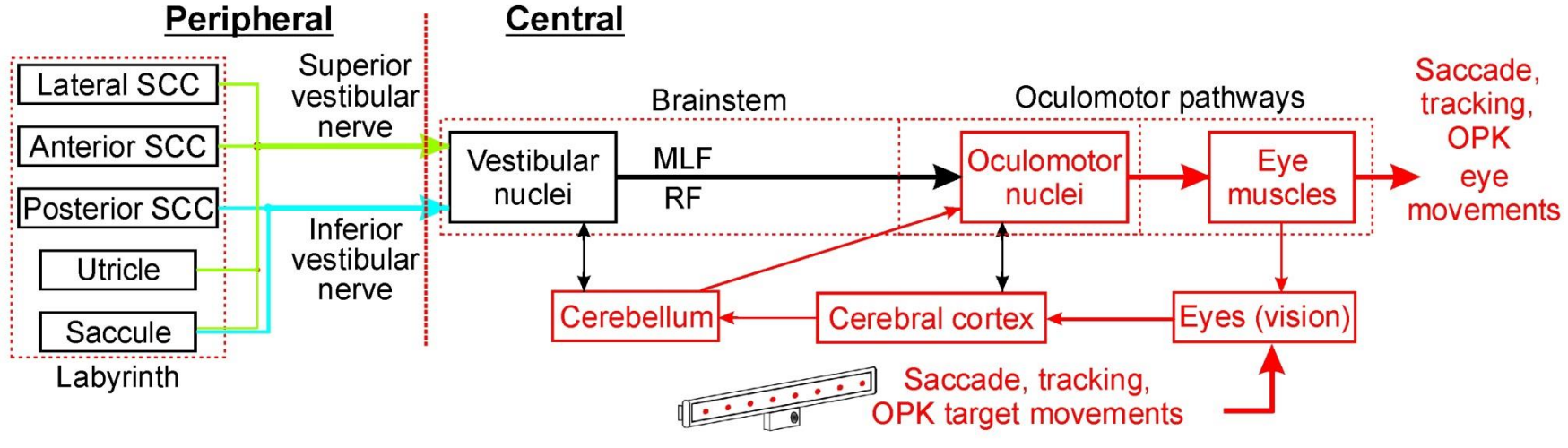
- Tests of oculomotor function (with fixation)
  - Saccade, tracking, optokinetic
- Tests of gaze stabilization (with fixation and without fixation)
  - Gaze/spontaneous nystagmus, static position
- Tests of vestibular function
  - Caloric
- Tests for specific etiologies
  - Dix-Hallpike maneuver (dynamic positioning), pressure (fistula)

Oculomotor Tests

Best Practices in Oculomotor Tests

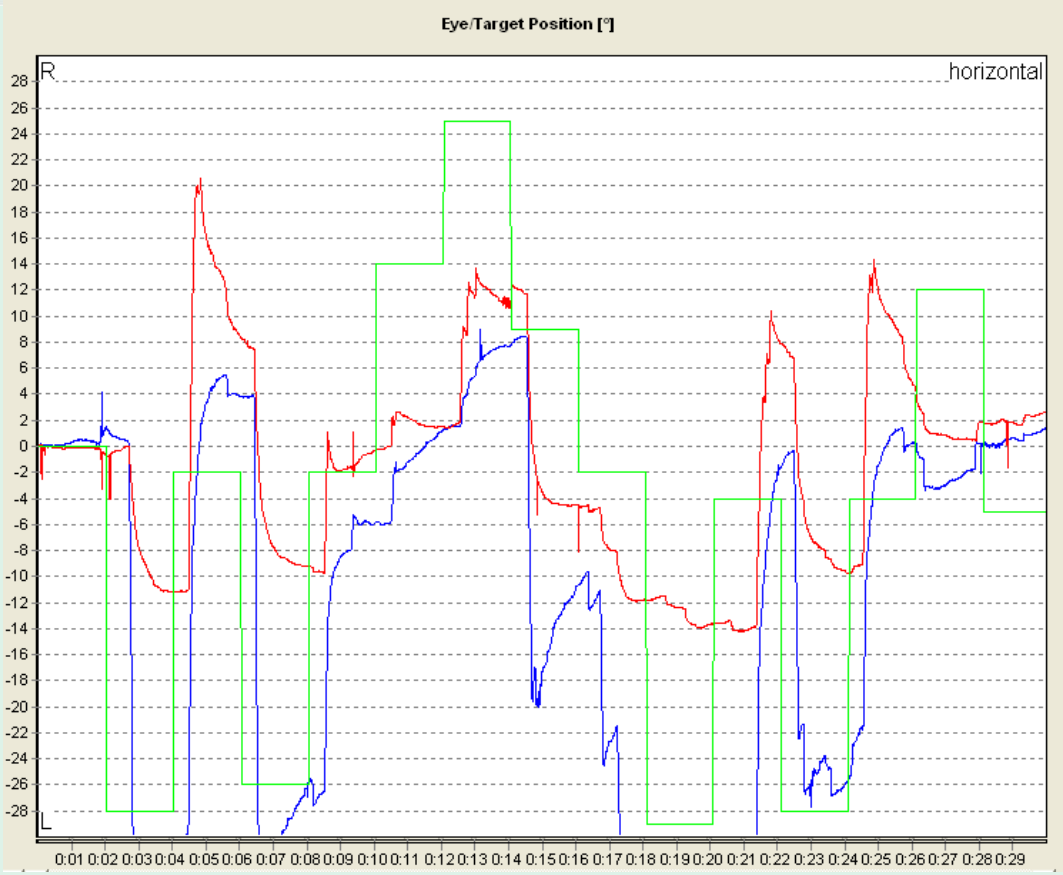
- Ask the patient to avoid head movements
- Ask the patient not to anticipate target movements
- Run the test as long as necessary to collect enough data
- Look for the patient’s best performance (repeat tests when necessary as true abnormalities are consistent and repeatable)
- Artifacts: watch for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

Interpretation of Oculomotor Tests



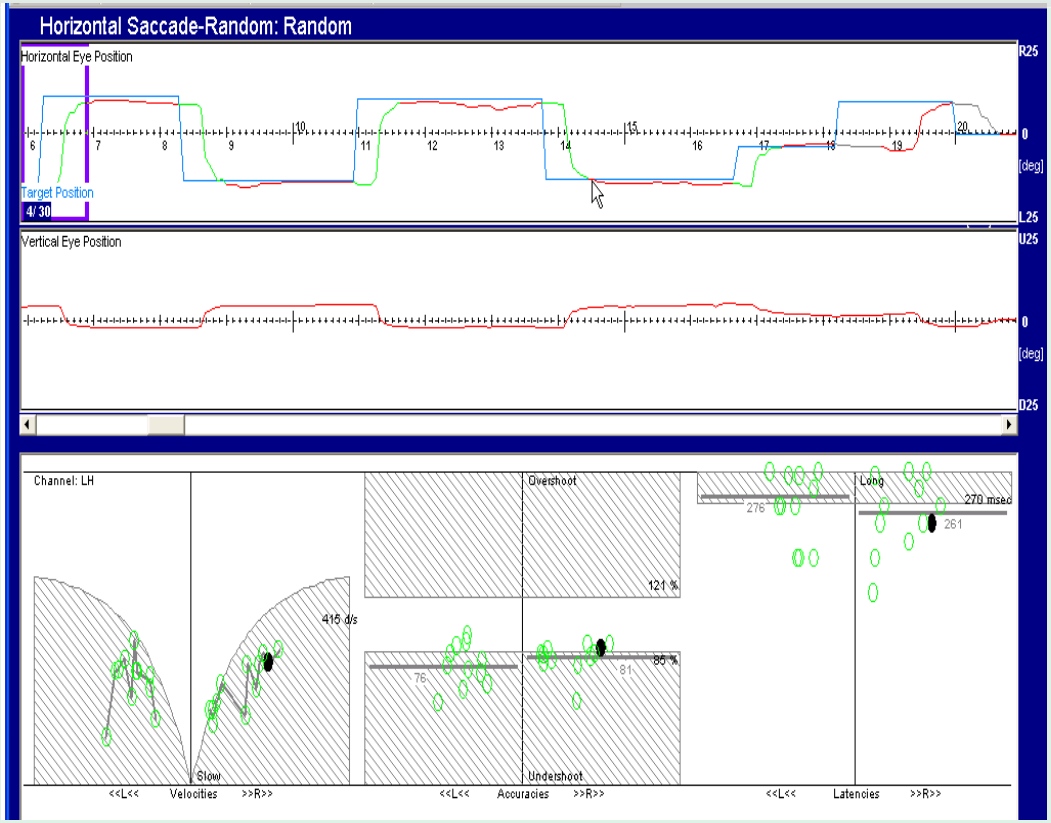
- Tests of oculomotor function (with fixation)
  - Saccade (fast eye movements)
  - Tracking (slow voluntary eye movements)
  - Optokinetic (reflexive eye movements but the test performed as a part of ENG/VNG using a light bar is not a true test of optokinetic pathways)
  - With very few exceptions (one?), abnormalities in the oculomotor tests indicate a central finding
  - Oculomotor tests provide hard and localizing findings but only about 5% of dizzy patients have abnormal findings in oculomotor tests
    - Rate of abnormal finding is only ~5% but artifacts are common

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

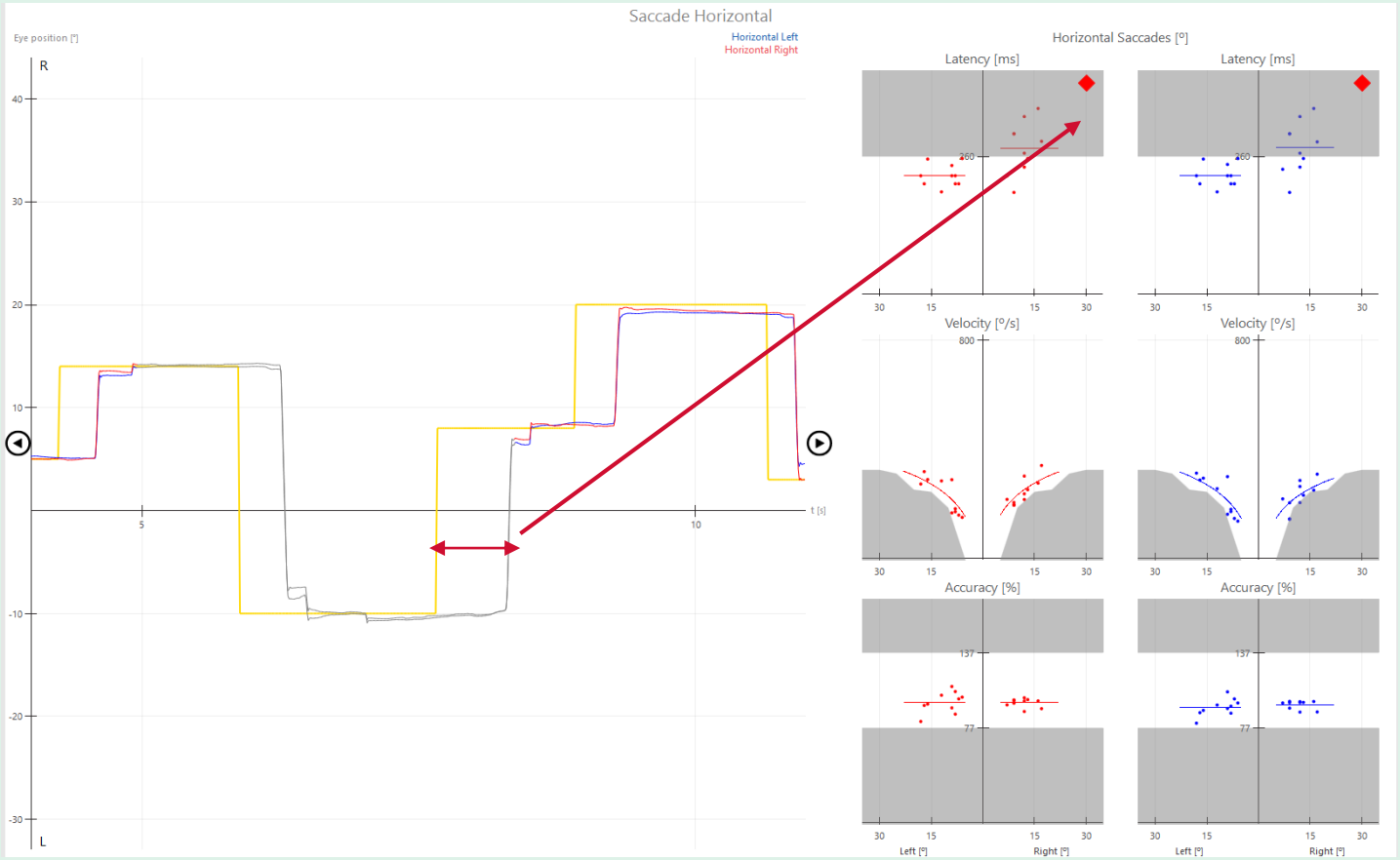
Abnormal Saccades - *Saccadic Slowing*



From: https://www.dizziness-and-balance.com/practice/saccades/slow%20saccade.htm

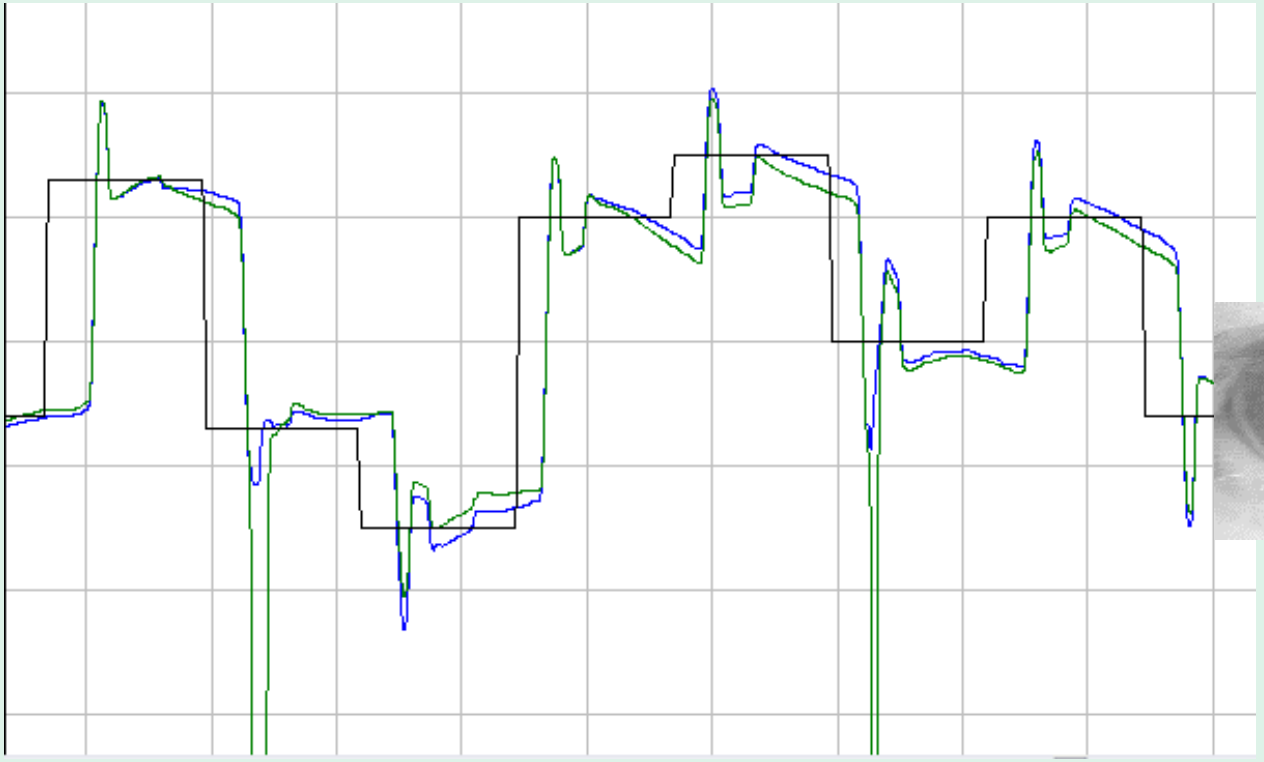
- *Saccadic slowing* denotes a central lesion in the basal ganglia, brain stem, cerebellum, peripheral oculomotor nerves or muscles (typically in diffuse lesions of the central pathways associated with neurodegenerative diseases)
  - May be due to fatigue, drowsiness, or medication (reversible)

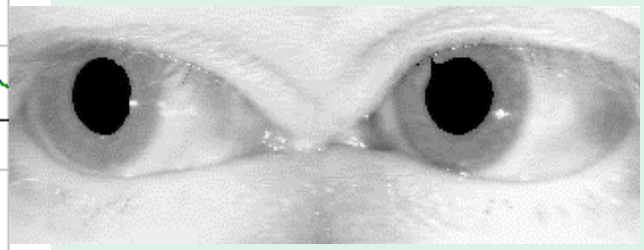
Abnormal Saccades – *Delayed*



- *Delayed saccades* (latencies >> 200 msec) denote a <u>central lesion</u> 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*

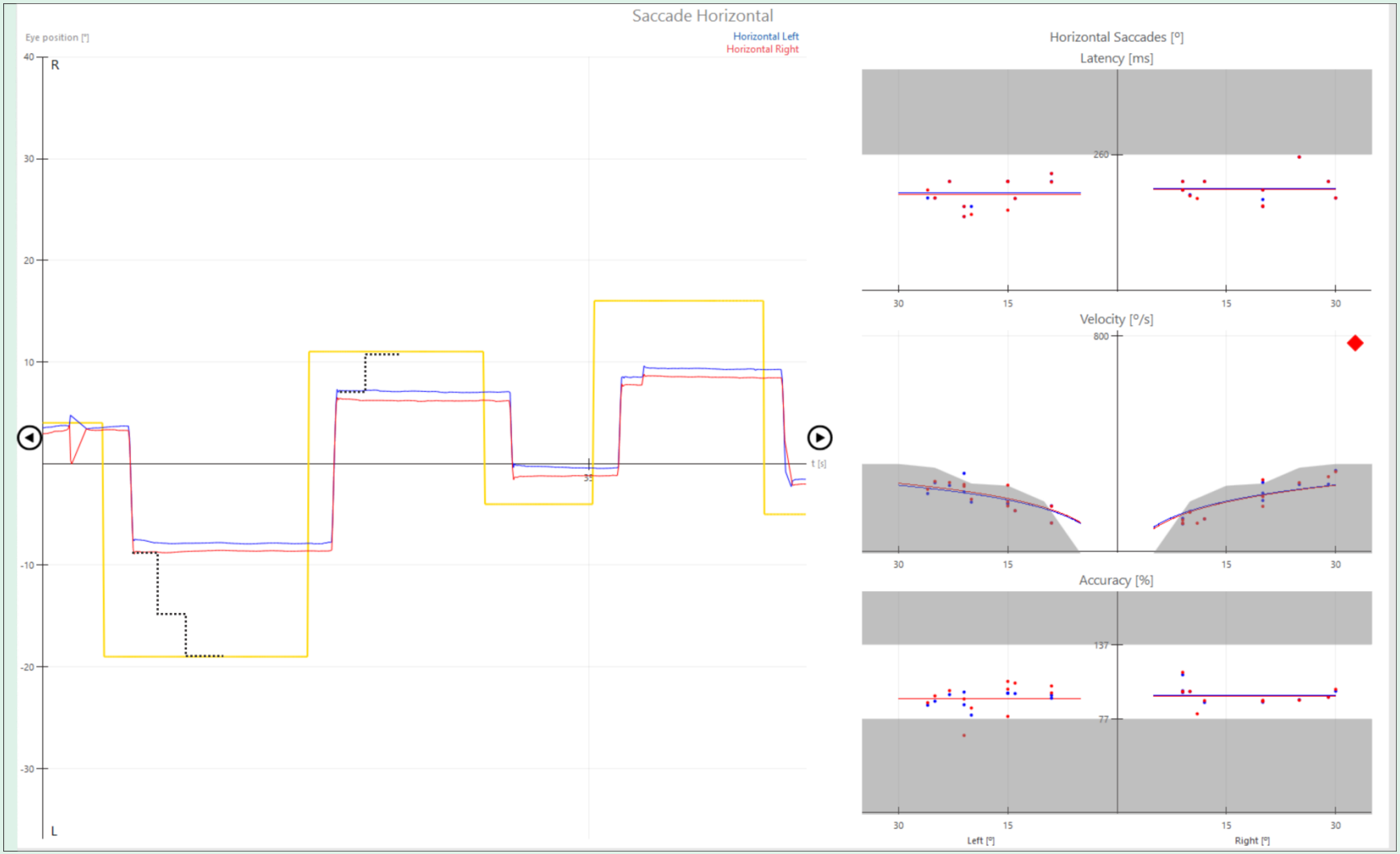




Hypermetria

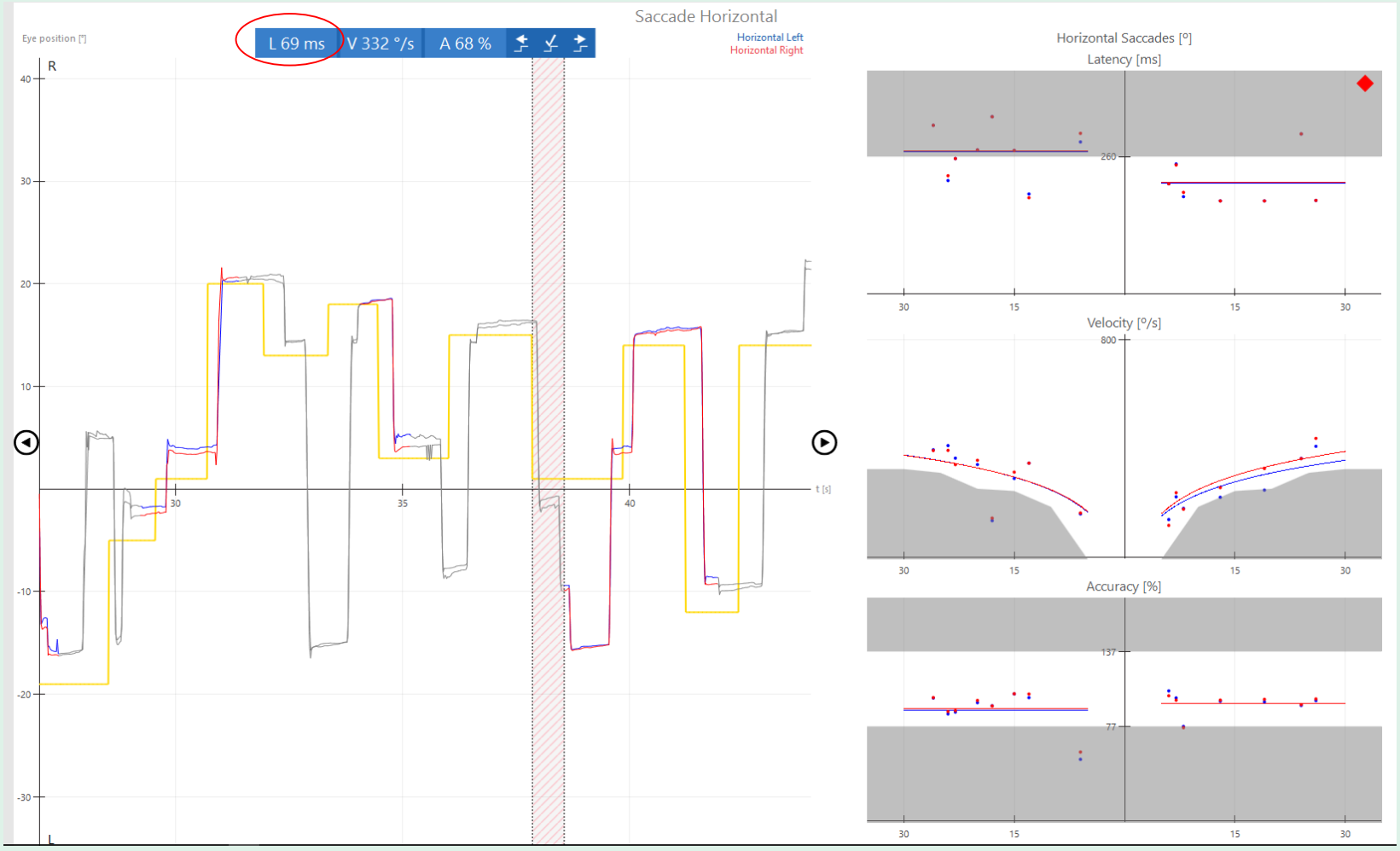
- *Saccadic dysmetria* denotes a central lesion in the cerebellar flocculus (hypometria) or the cerebellar vermis (hypermetria)

Saccade Test – *Artifacts*



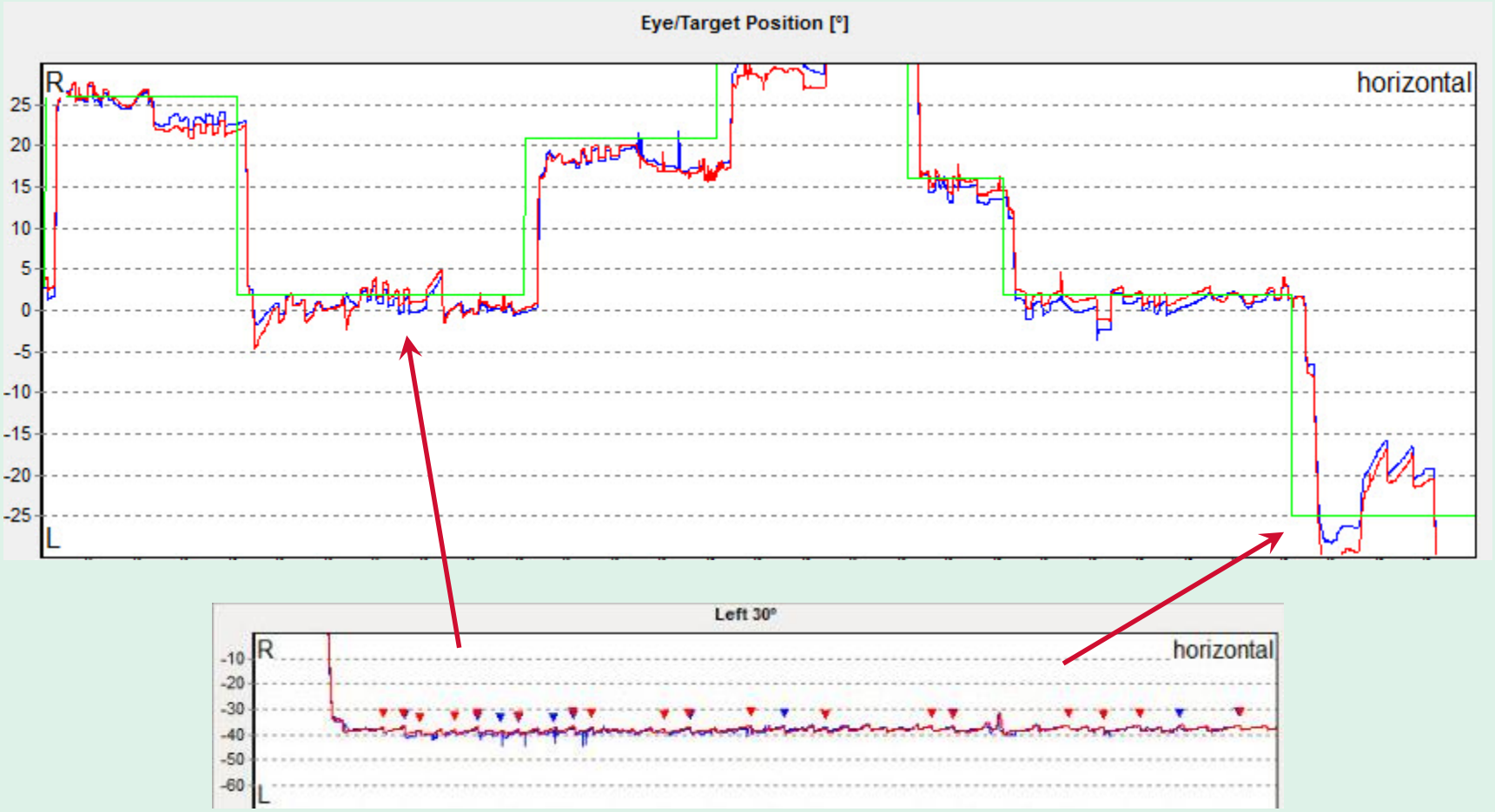
Saccades begin and end on the target. Check/repeat calibration.

Saccade Test – *Artifacts*



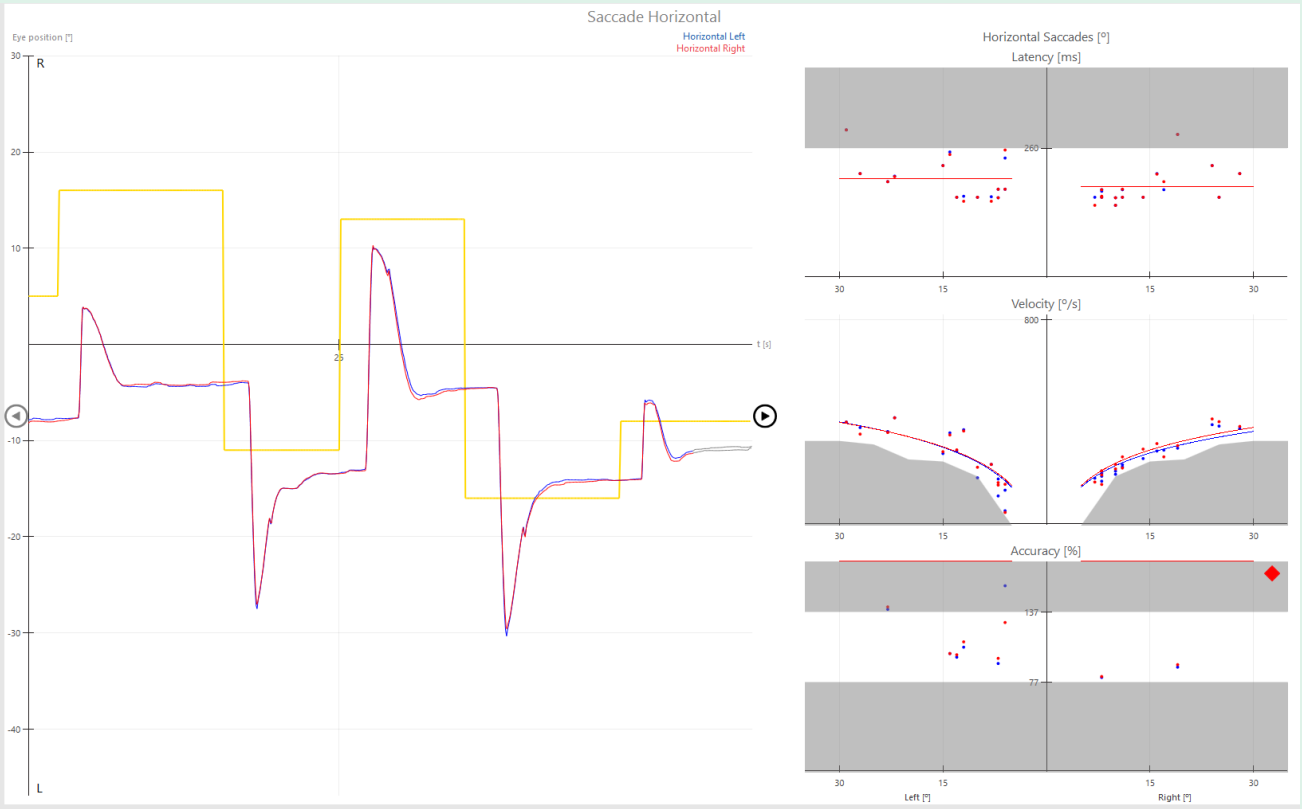
Patient is anticipating target movements (latency << 200 msec)

Saccade Test – *Artifacts*

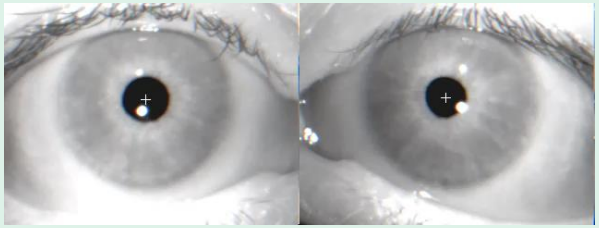


Superimposed gaze nystagmus

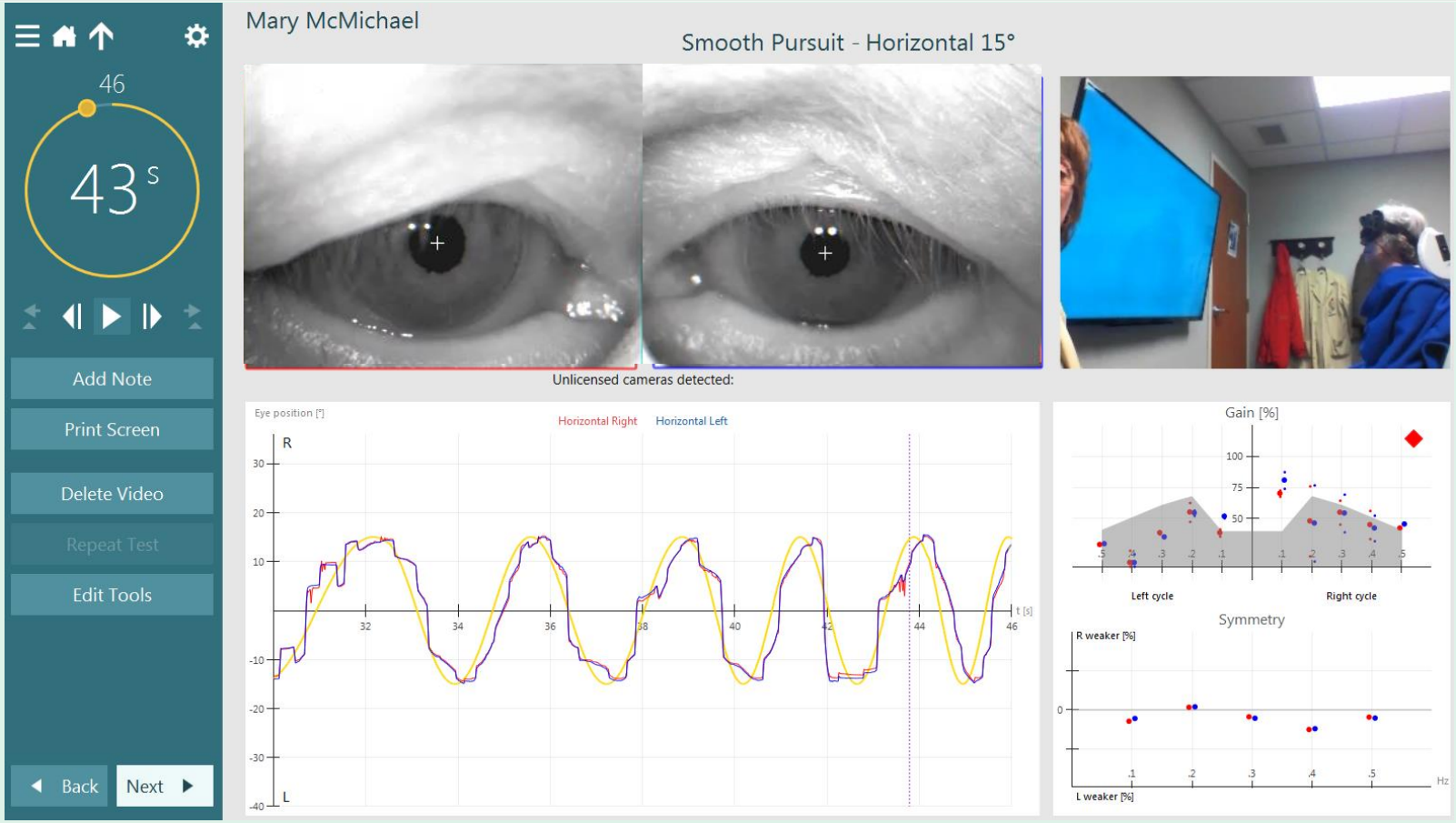
Saccade Test – *Artifacts*



Head movements

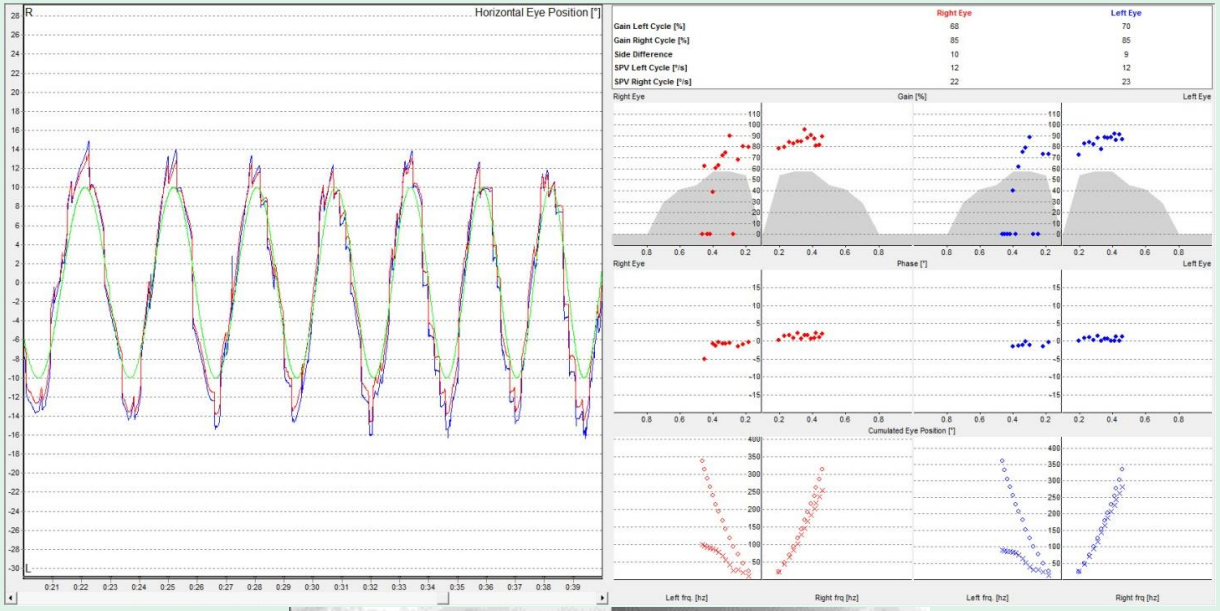


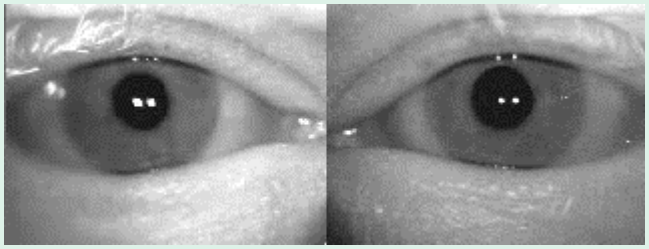
Abnormal Tracking - *Defective Pursuit*



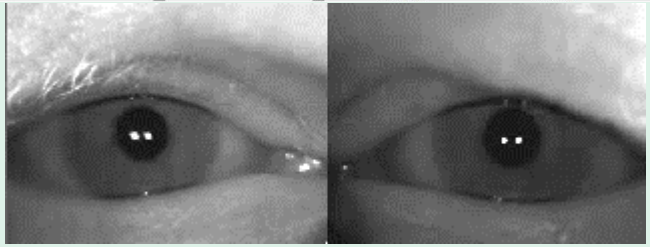
- *Defective tracking* (pursuit) denotes a central lesion. If symmetric – diffuse cortical, basal ganglia, or cerebellar diseases. If asymmetric – focal lesions involving ipsilateral cerebellar hemisphere, brain stem, or parieto-occipital region.

Tracking Test – *Pitfall or Abnormal Tracking?*



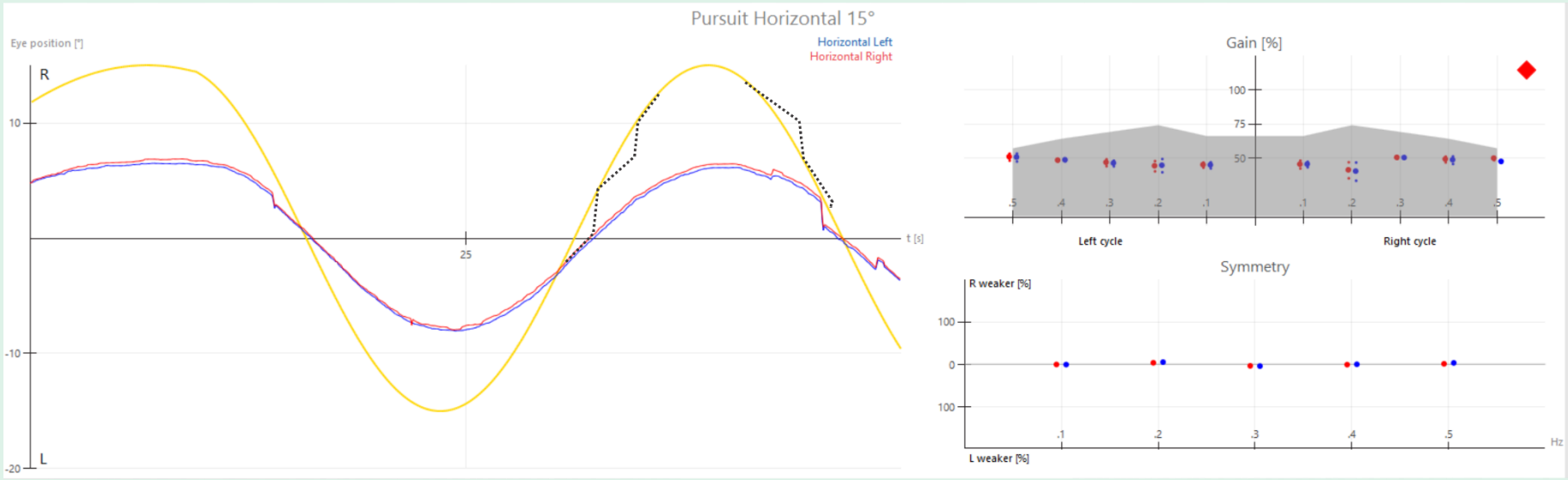


Spontaneous nystagmus



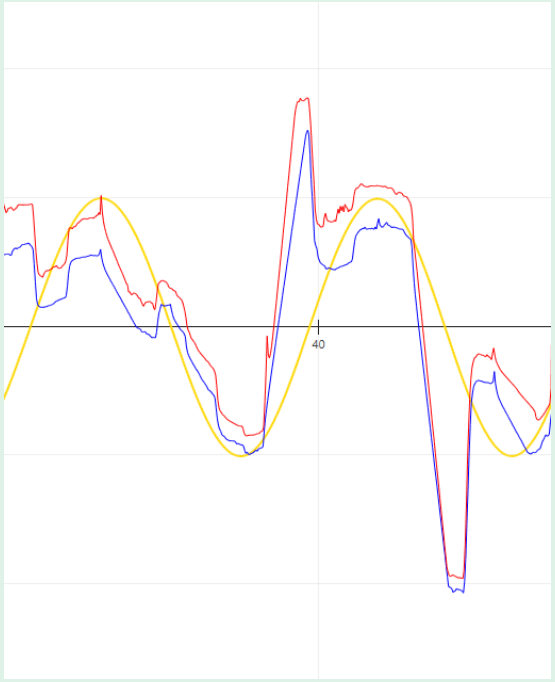
- Borderline unilateral defective tracking can be caused by strong spontaneous nystagmus (in the direction of fast phases)
  - Effect of superimposed nystagmus and not abnormal tracking

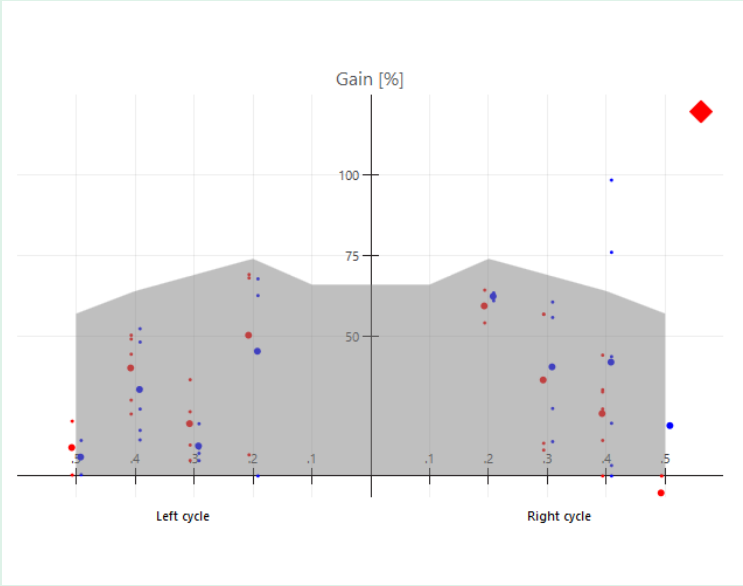
Smooth Pursuit/Tracking Test – *Artifacts*



Peaks must match at least for low freq. Check/repeat calibration.

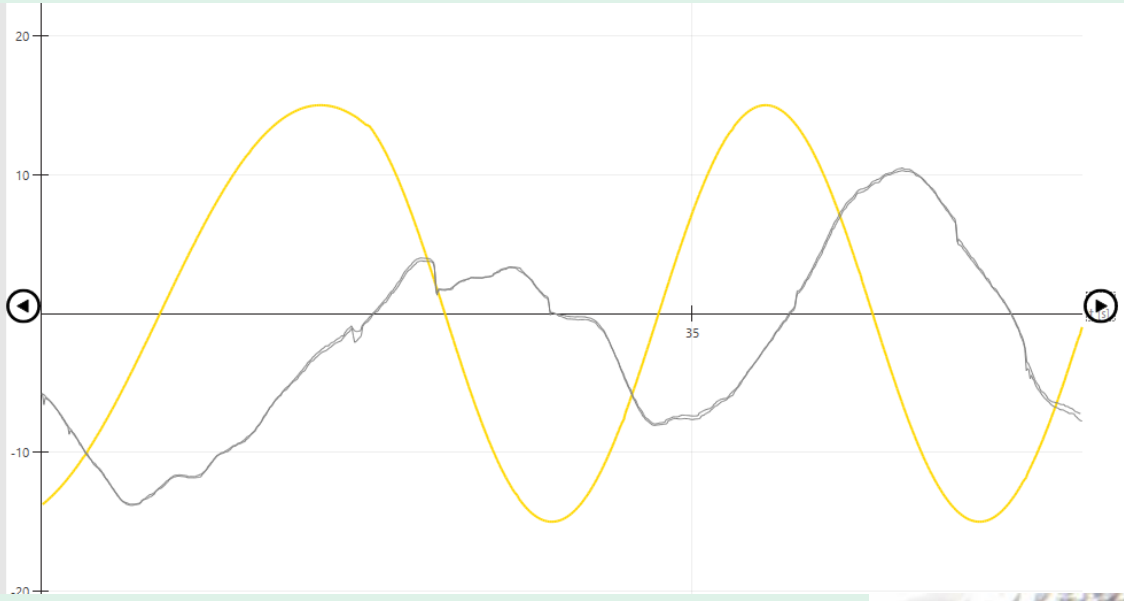
Smooth Pursuit/Tracking Test – *Artifacts*

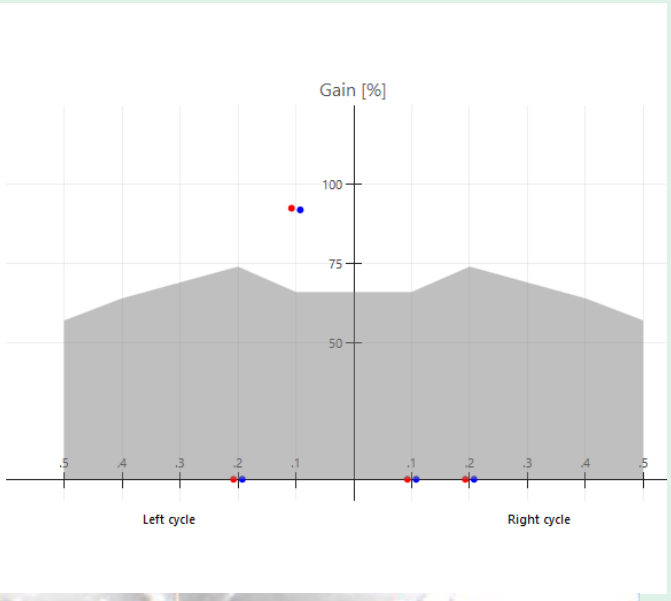




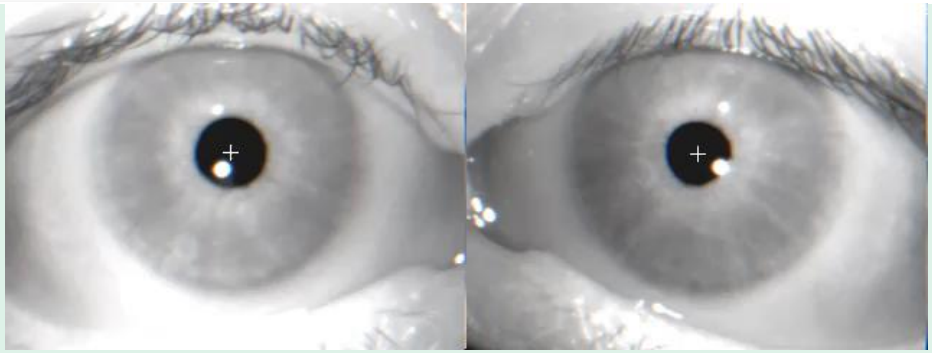
Inattention, repeat after instructing the patient.

Smooth Pursuit/Tracking Test – *Artifacts*

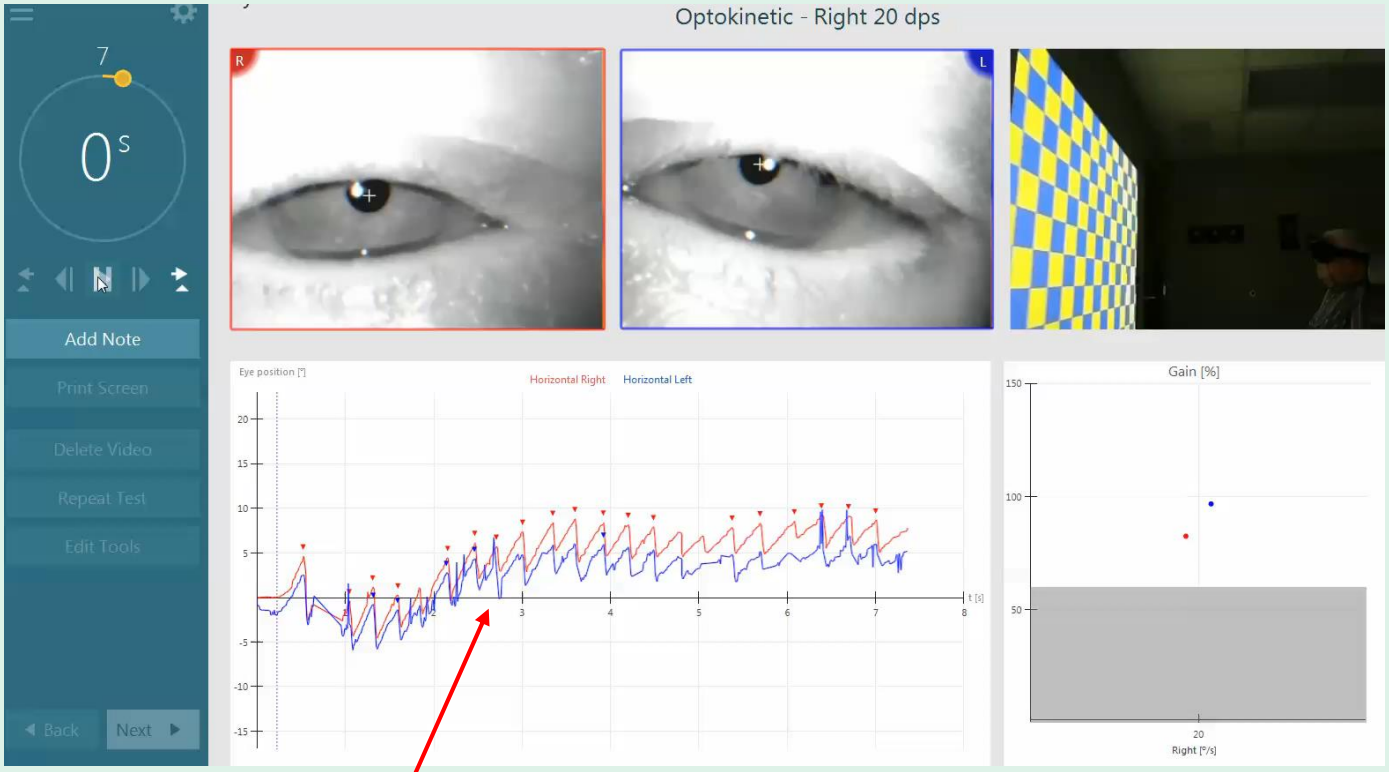




Head movements



Optokinetic Test – *Procedure*



Look OPK nystagmus

(instruction: follow the scene all the way)

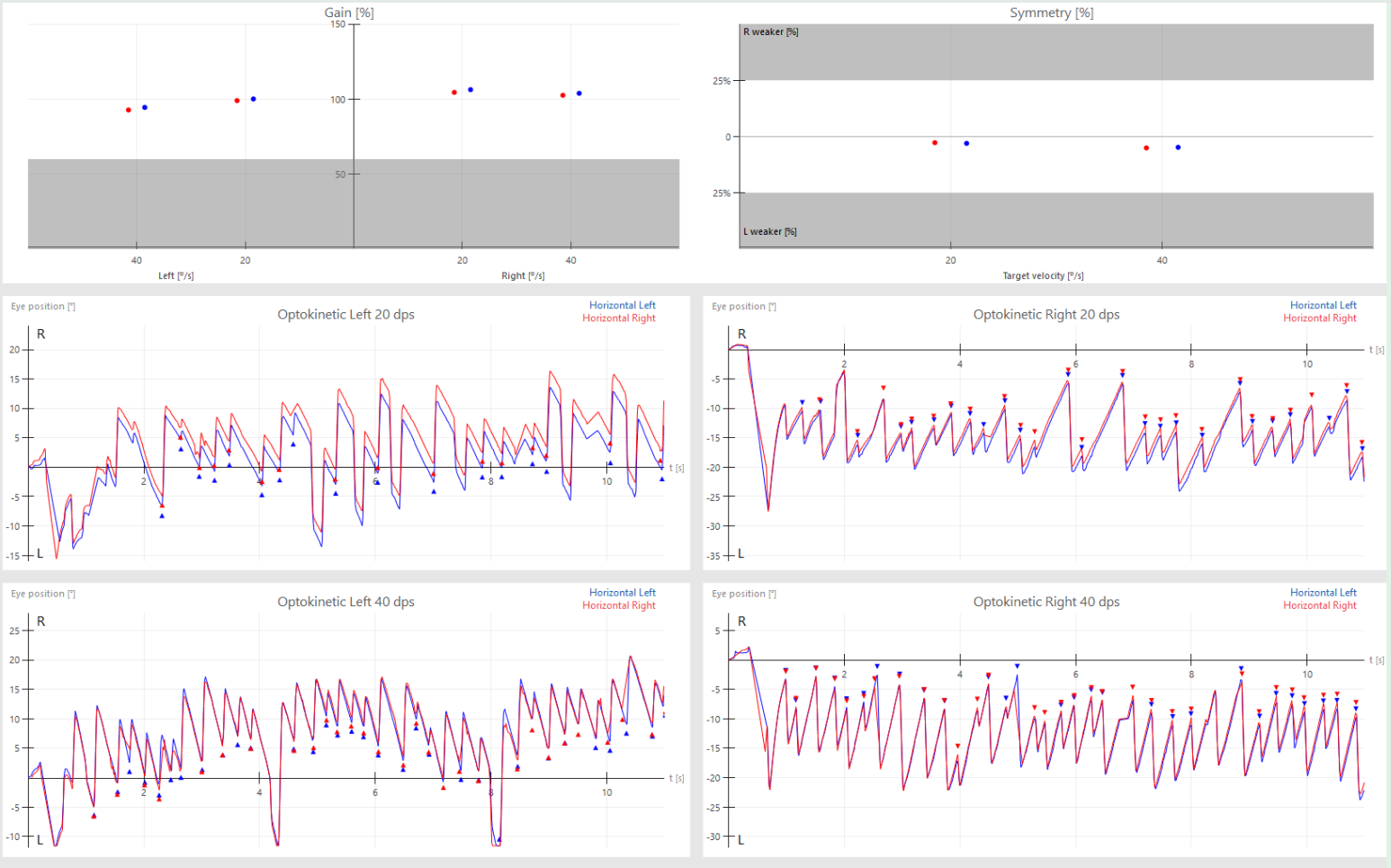
Stare OPK nystagmus

(instruction: follow the scene around the center)

Nystagmus slow phase matches target direction and velocity

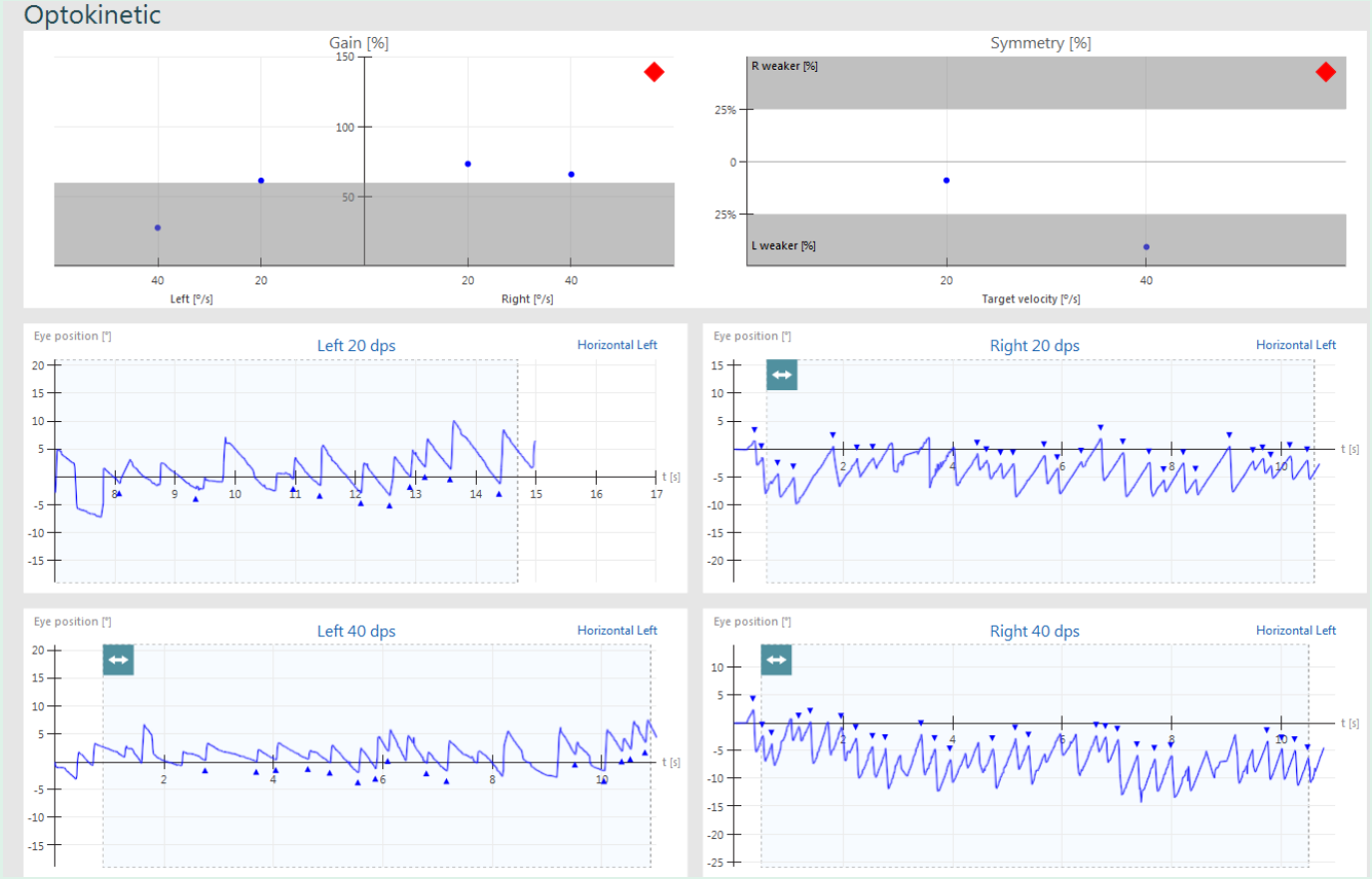
Instructions may not make much difference in the interpretation of the test results. Use the instruction that is easier for the patient to follow.

Optokinetic Test – *Normal Results*



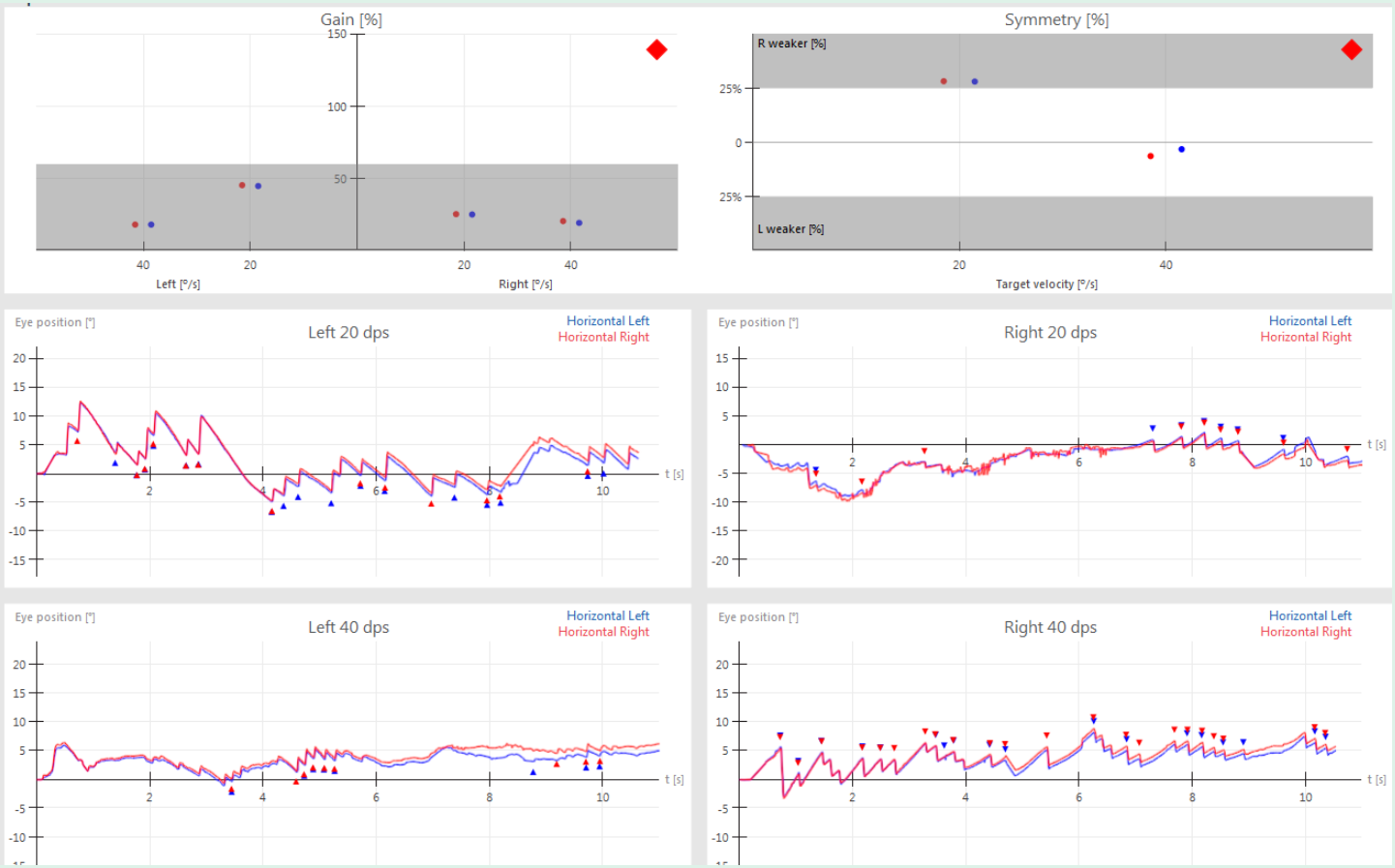
- Normative values for OPK are not well-defined and are usually not adjusted for age
- Qualitative assessment of OPK results is usually adequate

Abnormal OPK – *Reduced Nystagmus Intensity*



- Could be unilateral or bilateral, for all velocities or for high velocities only
- Rule out faulty calibrations
- Rule out presence of spontaneous nystagmus

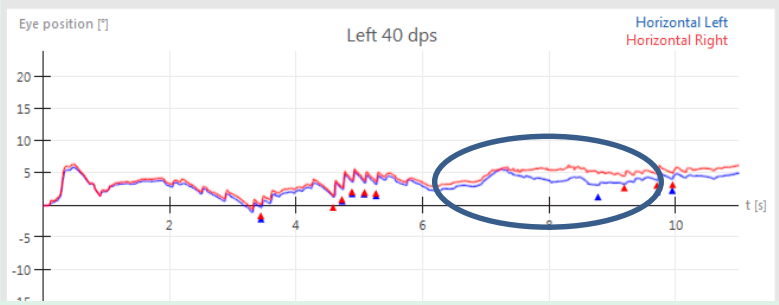
Correlations in Oculomotor Tests – *Tracking & OPK*

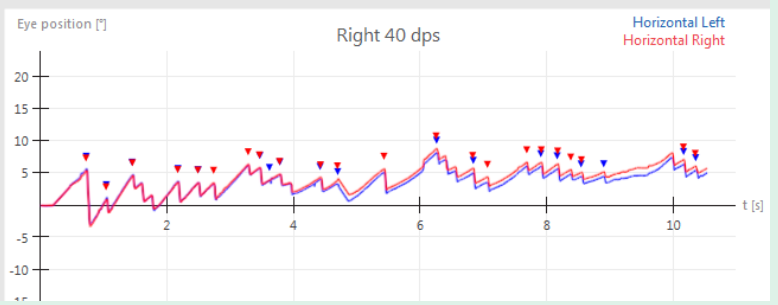


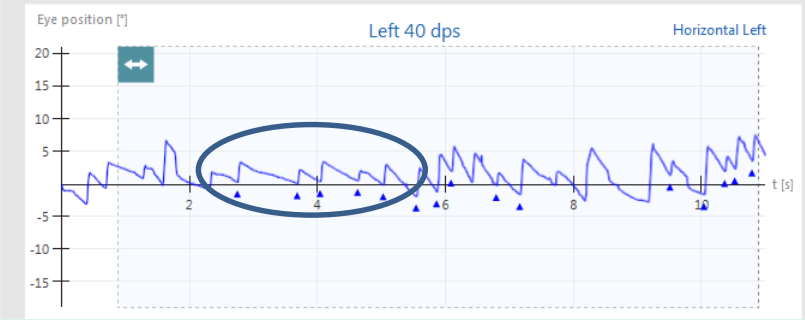
Quantification of OPK results is often unnecessary and qualitative analysis is sufficient

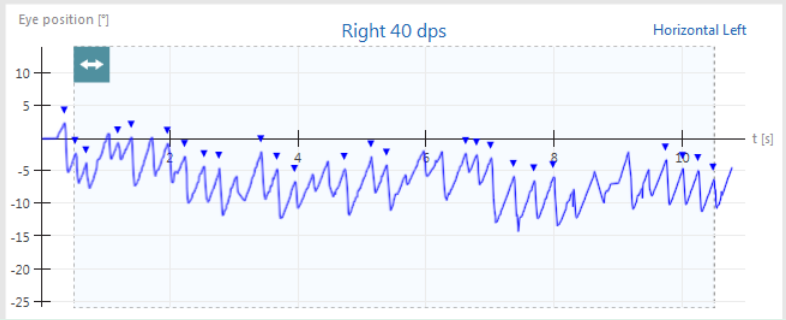
- OPK and tracking test results should be similar *<u>when</u>* equivalent test parameters are used and if age effects are considered
  - In case of conflict, investigate more

OPK Test – *Pitfalls*









Intermittent OPK nystagmus (look for peak velocities)

Gaze Stabilization Tests

Best Practices in Gaze Stabilization Tests

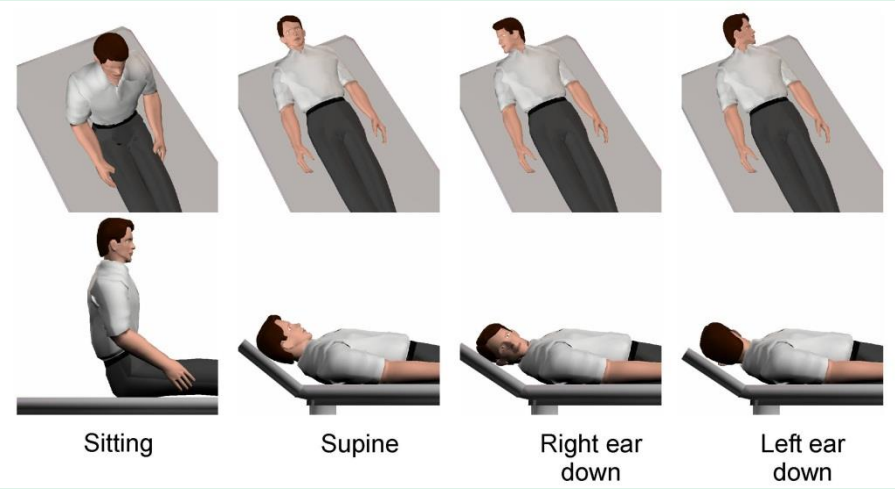
- Purpose – to examine the patient's ability to maintain steady gaze in different conditions (most common manifestation of gaze instability is nystagmus)
  - Gaze test – gaze stability in different off-center gaze positions
  - Spontaneous nystagmus test – gaze stability in the absence of vestibular 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

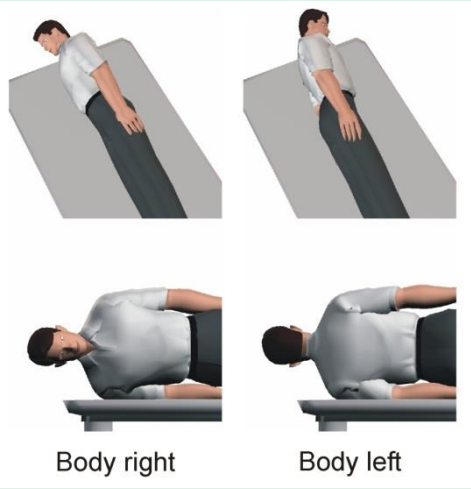
Best Practices in Gaze Stabilization Tests

- 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)

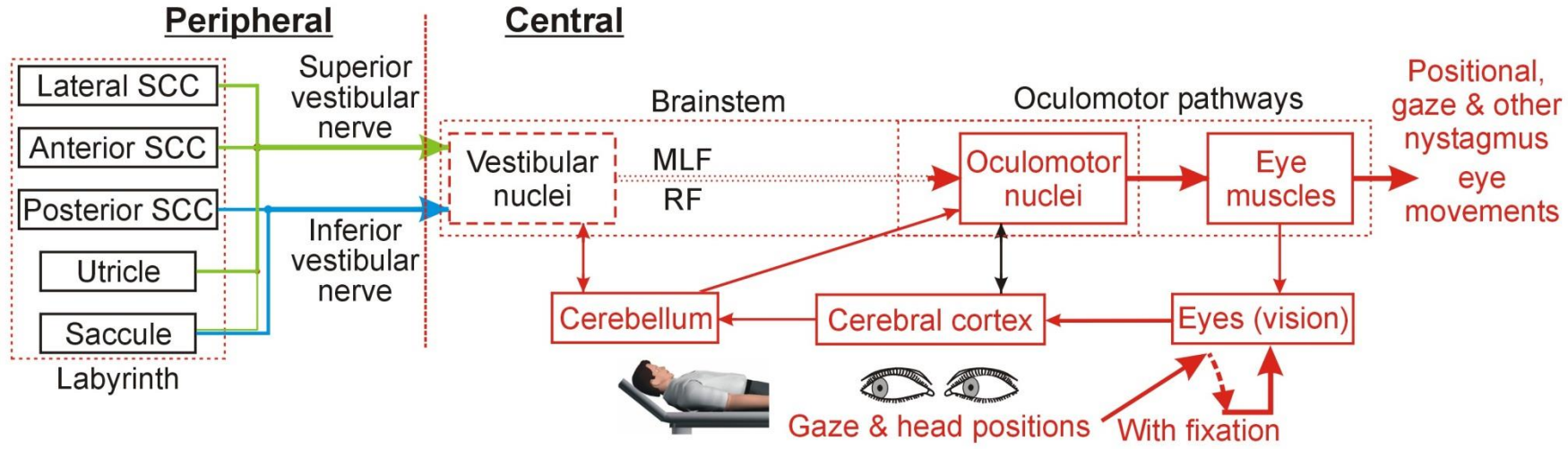




General Interpretation of Gaze Stabilization Tests

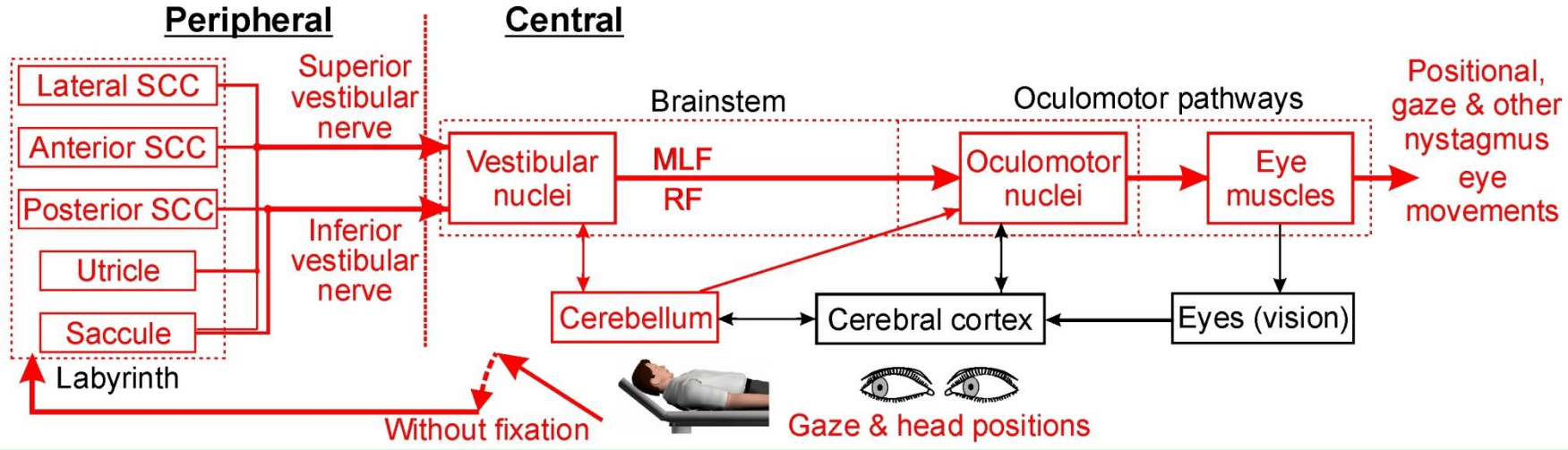
- The following information is needed for interpretation:
  - Presence of nystagmus in any gaze/head positions
  - Direction of nystagmus in any gaze/head positions
  - Intensity of nystagmus in any gaze/head positions (primarily for tests without fixation)
  - Effect of fixation on the presence or intensity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

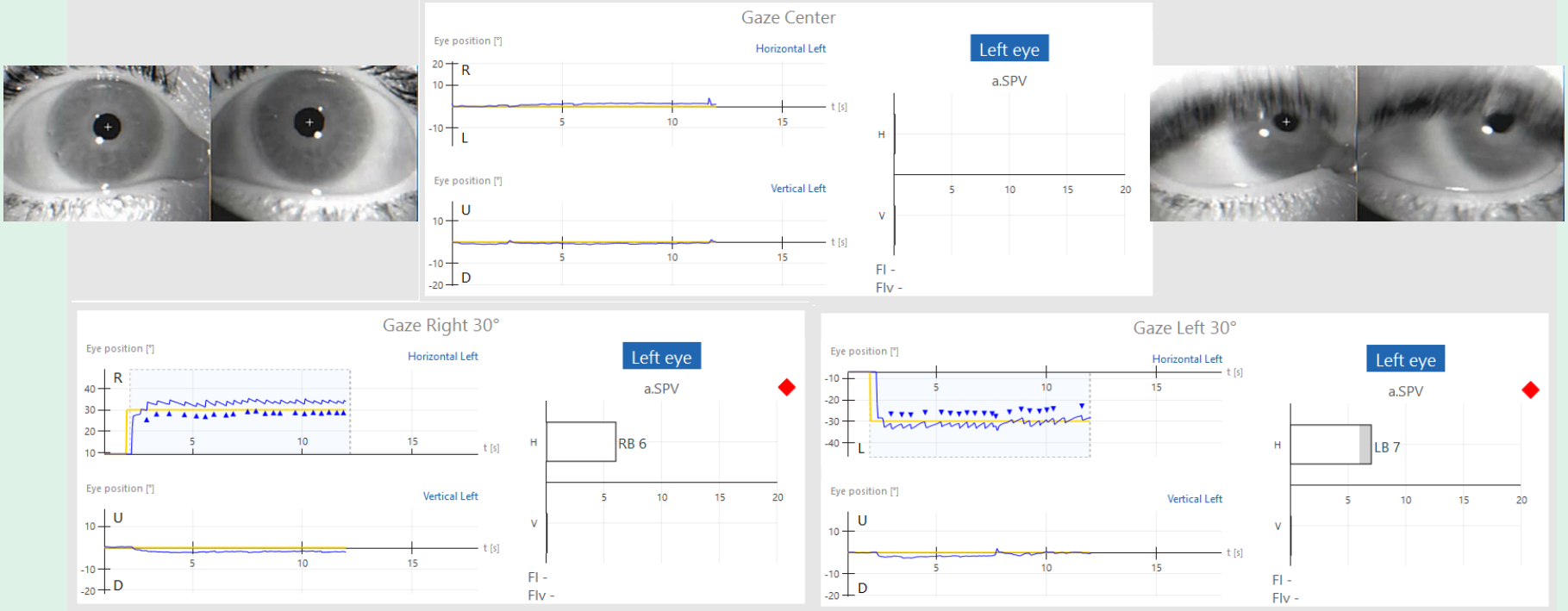


- Abnormalities in tests of gaze stabilization without fixation (spontaneous nystagmus and static position tests) are typically non-localizing
  - Can support localizing findings in other vestibular tests

General Interpretation of Gaze Stabilization Tests

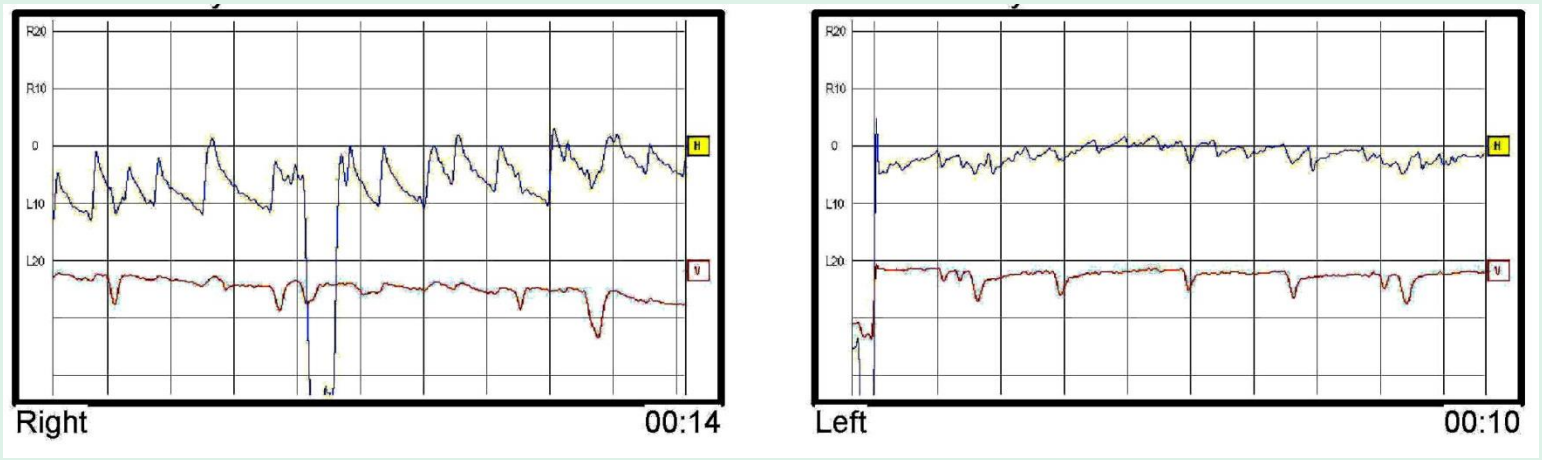
- For horizontal nystagmus:
  - Changes direction in a single gaze position → Central
  - Is present with fixation and its intensity does not increase significantly (at least doubles) without fixation → Central
  - Is present without fixation and its intensity is less than a threshold (6º/sec in ENG,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

Abnormal Gaze – *Symmetric Gaze-Evoked Nystagmus*



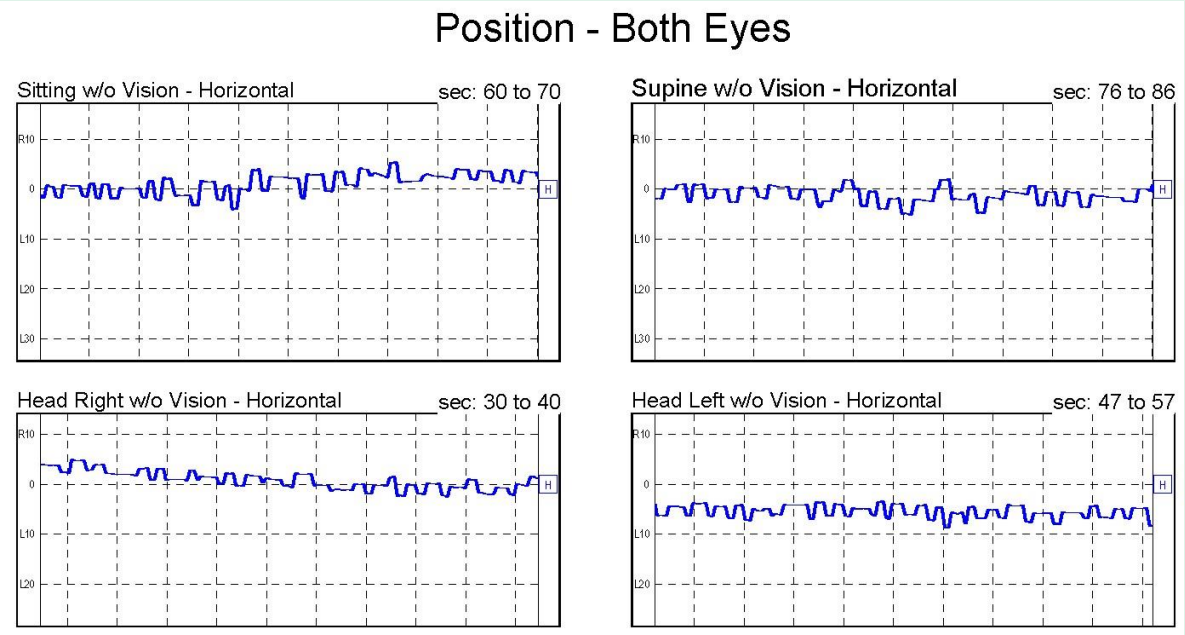
- *Gaze-evoked nystagmus* denotes a central lesion in the cerebellum or brain stem (common in lesions of cerebellar flocculus)

Abnormal Gaze – *Asymmetric Gaze-Evoked Nystagmus*

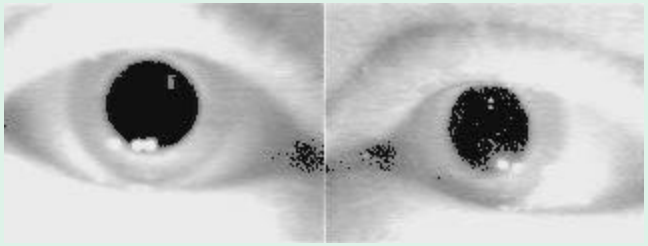


Brun’s nystagmus

Abnormal Gaze Stabilization – *Saccadic Intrusion*

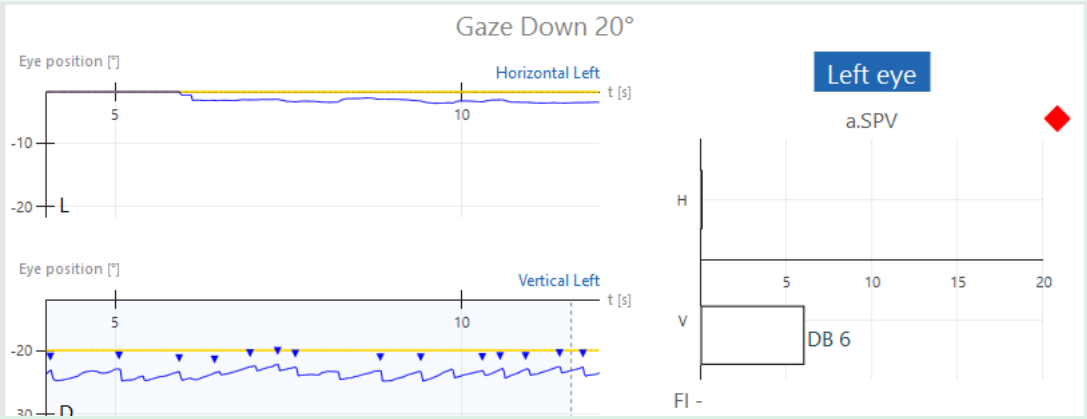


Square wave jerk nystagmus



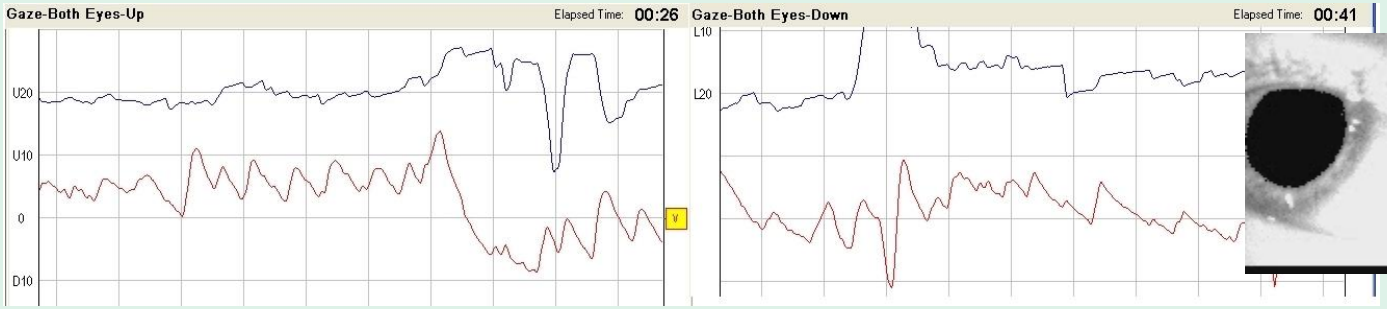
- Normal limits
  - Abnormal only when present with fixation
  - Estimates of normal limits for amplitude, frequency, age dependency, etc. vary due to differences in recording methods (frequency increases with age)
- Localization
  - *Square wave jerk nystagmus* denotes a central lesion in the cerebellum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

Abnormal Gaze Stabilization – *Vertical Nystagmus*



Downbeat nystagmus

Upbeat nystagmus

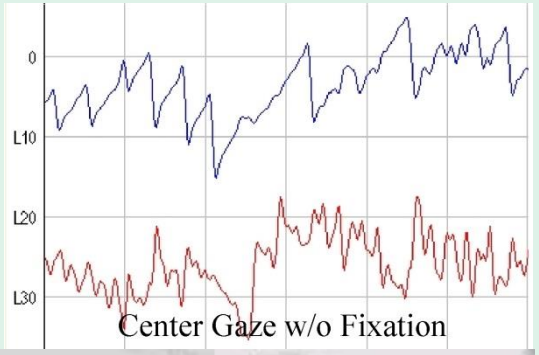


- *Downbeat or upbeat gaze nystagmus* with fixation denotes a central lesion in the cerebellum or underlying medulla
  - Upbeat nystagmus is more commonly associated with side effects of medications, nicotine, or alcohol
- *Vertical nystagmus without fixation* that exceeds the normal limit (7°/sec) denotes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

Abnormalities in the Gaze Stabilization Tests

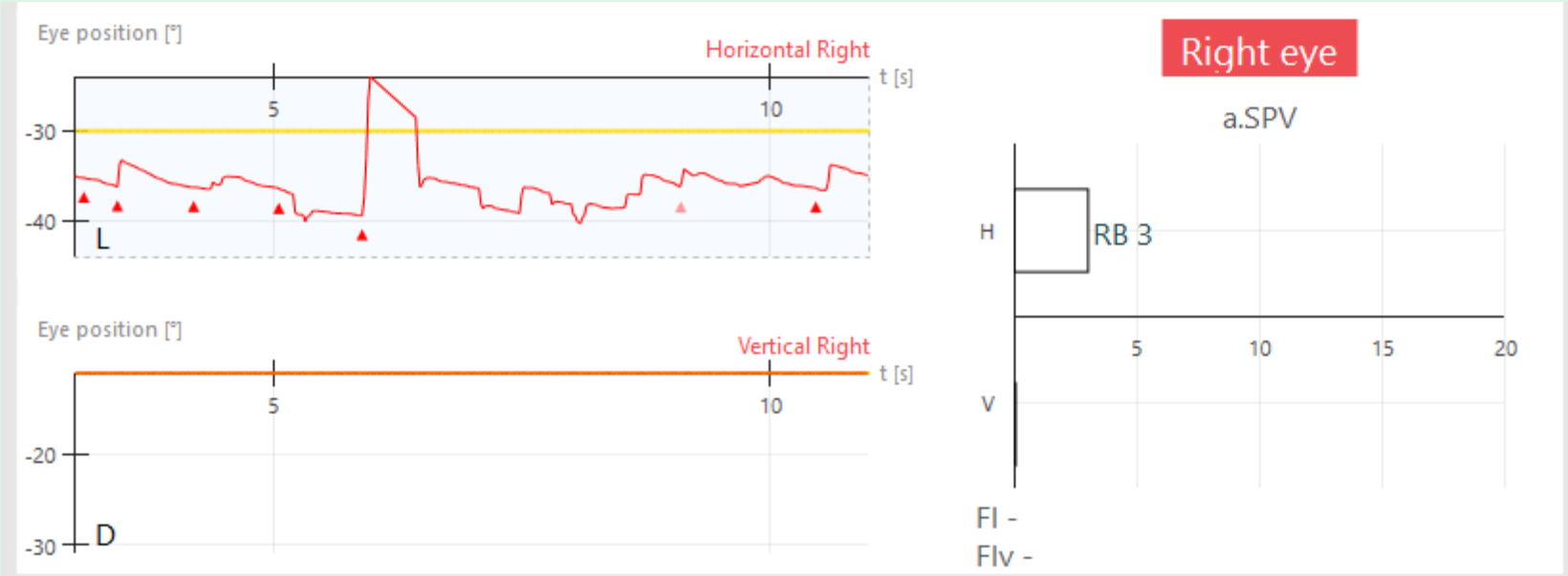
- Vestibular (spontaneous) nystagmus
  - Horizontal with or without torsional component or vertical with torsional component (in lesions involving vertical canals)
  - Horizontal and vertical components suppressed with fixation
    - Intensity decreases by at least 50%
  - Intensity may vary due to gaze position and alertness level
    - Stronger when gaze directed toward fast phases
  - Direction may vary in <u>different</u> 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 – 6º/sec in ENG, 4º/sec in VNG
    - Vertical – 7º/sec in VNG (upbeat more common in normal individuals)

Spontaneous Nystagmus



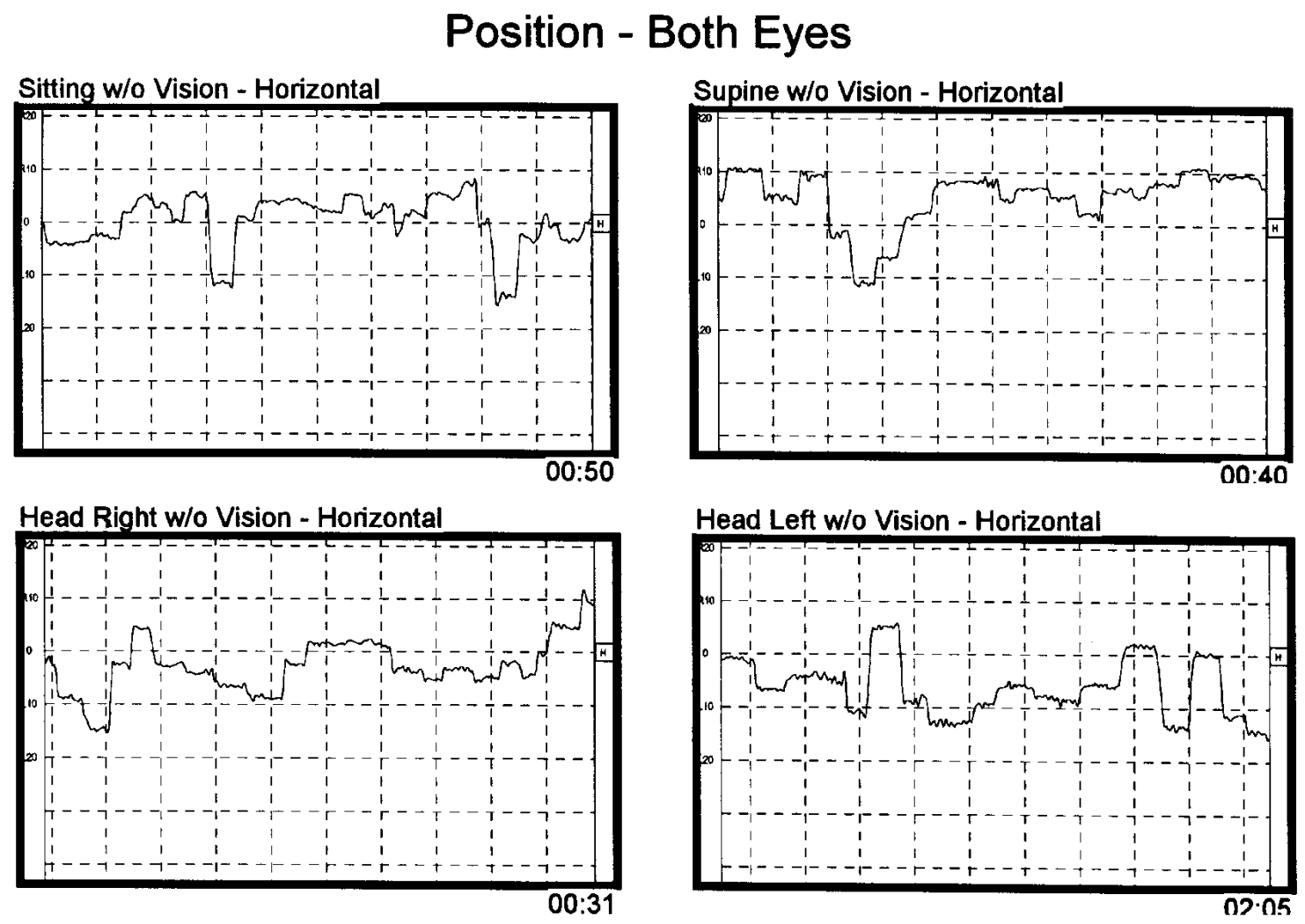
- Conjugate
- Linear slow component
- When nystagmus is strong, it can be seen with and without fixation but the intensity of horizontal and vertical component are significantly more (at least by a factor of 2) without fixation
- Nystagmus direction does NOT change but the intensity may vary in different gaze positions
  - Stronger when gaze directed toward fast phases (Alexander's law)

Static Position Test – *Pitfalls*



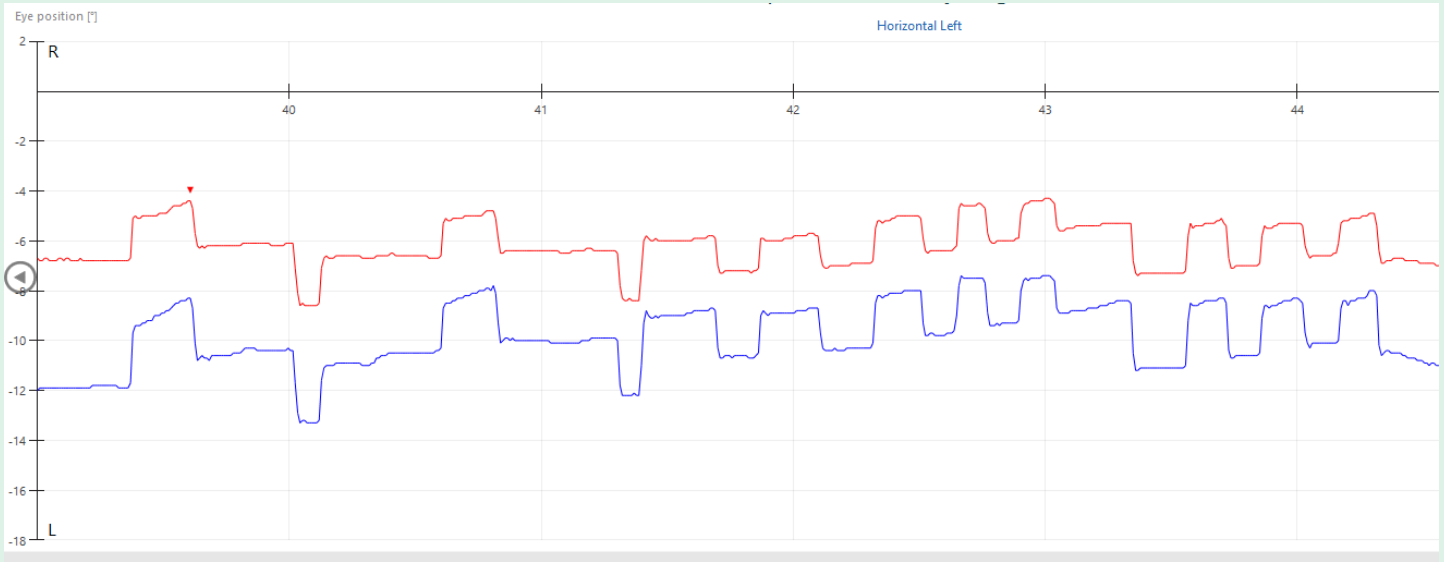
Nystagmus intensity < threshold (6°/sec in ENG or 4°/sec in VNG) in some or all head positions (without fixation)

Static Position Test – *Artifacts*



Patient is looking around

Static Position Test – *Pitfalls*



Square wave jerk nystagmus. Abnormal with fixation, normal without if not too frequent.

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)

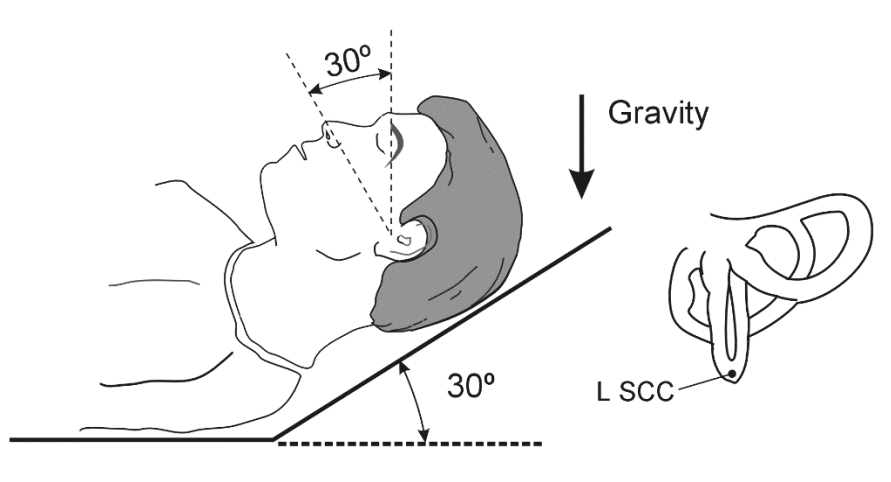
Caloric Test – *Common Irrigation Parameters*

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

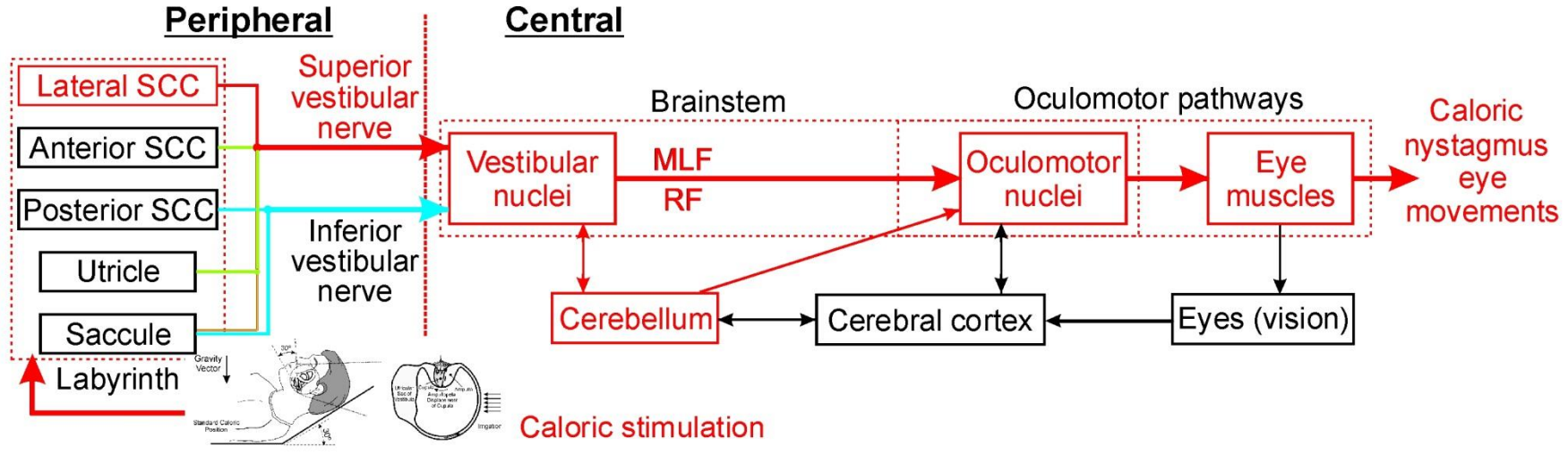
- Order of Irrigations
  - Start with one temperature and irrigate ears in the same order for each temperature (ANSI recommends starting with warm)
    - Starting with cool irrigations may reduce the typical difference between warm and cool responses (Noaksson et al, 1998)
- ANSI recommendation to disallow air is based on outdated studies
  - Continue using air irrigators but remember that air is technically more challenging and requires a longer learning period
- 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:
    - No oculomotor abnormalities
    - No gaze/spontaneous nystagmus
    - Less than 10% of right-left asymmetry for warm irrigations

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|> 6°/sec (4°/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.

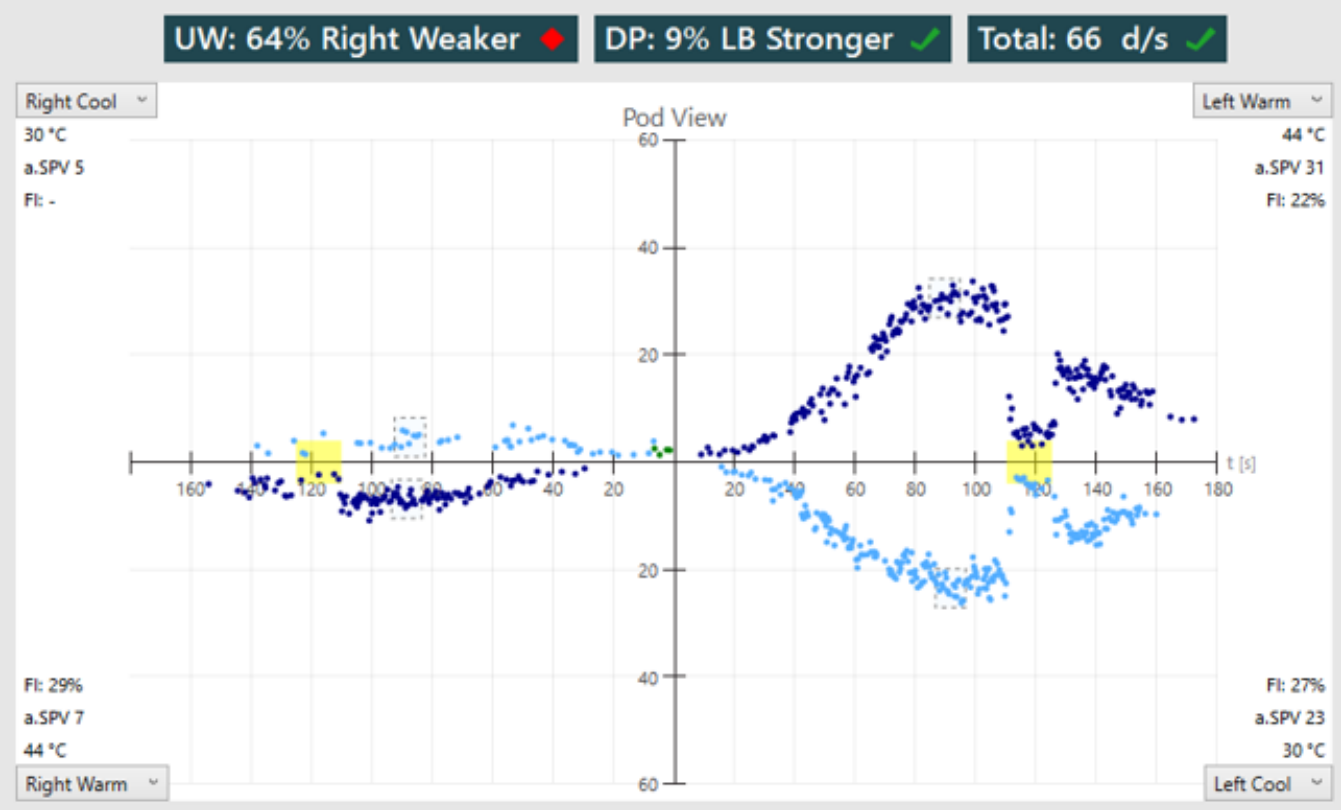
Interpretation of Caloric Test



- 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

Caloric Test – *Data Analysis*

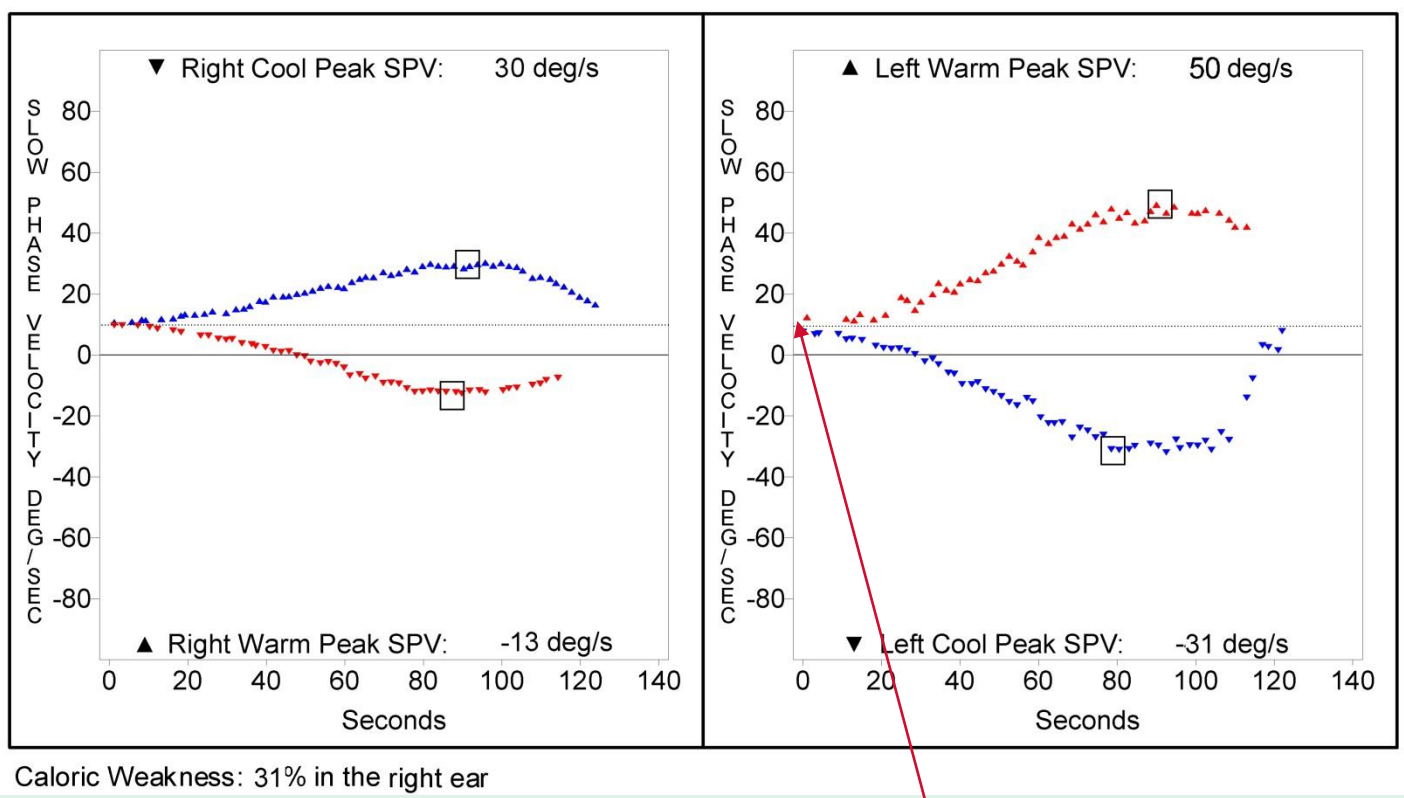
Total RE =
5+7= 12°/sec



Total LE =
31+23=
54°/sec

- Determine total responses from each ear
- If total responses of both ears < normal limits (Total RE <12° & Total LE <12°)
  - Bilateral caloric weakness. Stop calculations - UW & DP values are not valid!
  - Statically compensated/chronic lesion (no spontaneous nystagmus/baseline shift)

Abnormal Calorics – *Unilateral Weakness*



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

Uncompensated/acute lesion (significant nystagmus without fixation/baseline shift)

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 end-organ to 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*

Tot R = 4+5 = 9 < 12

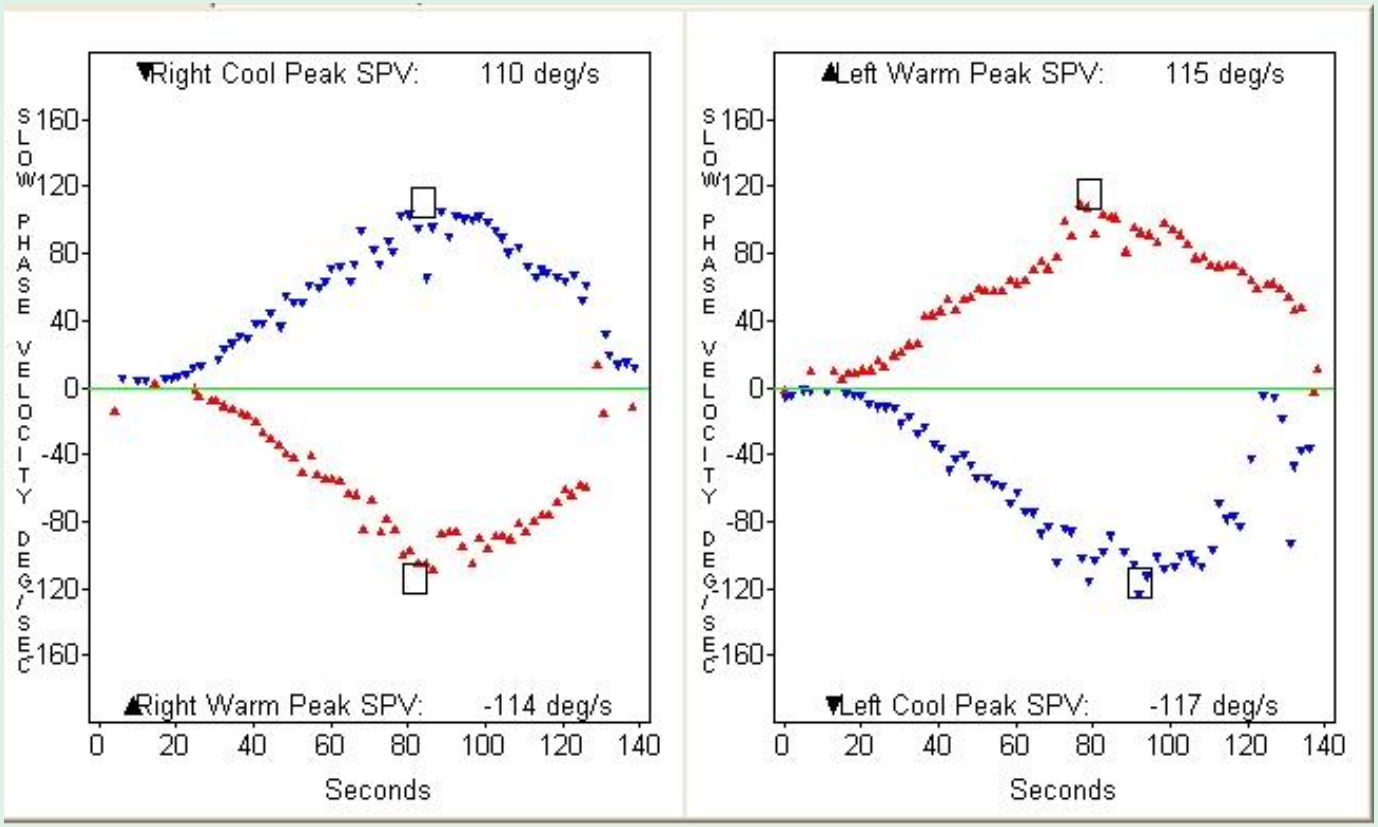
Tot L = 3+3 = 6 < 12

- 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*



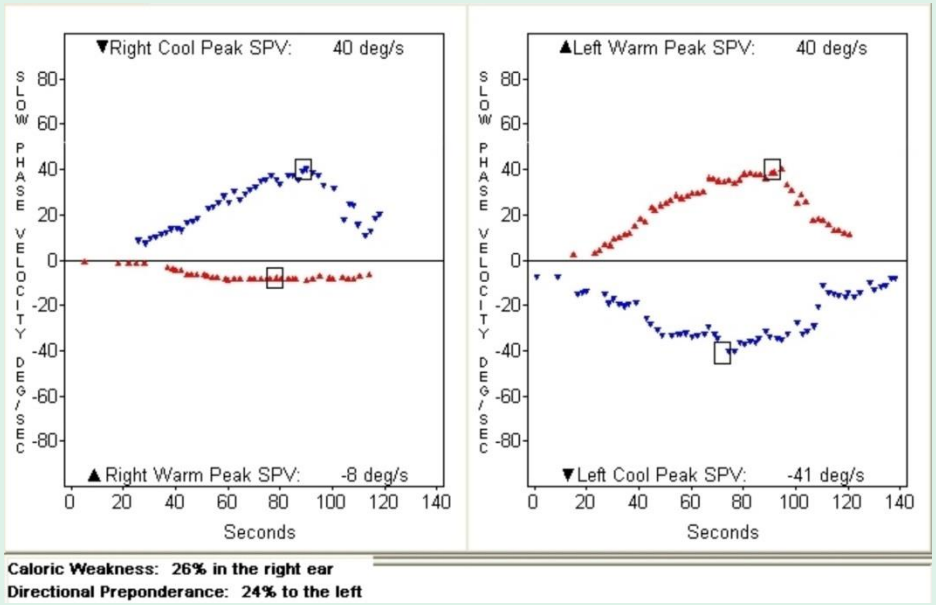
Total RE = RC - RW = 224°/sec Total LE = LW - LC = 232°/sec

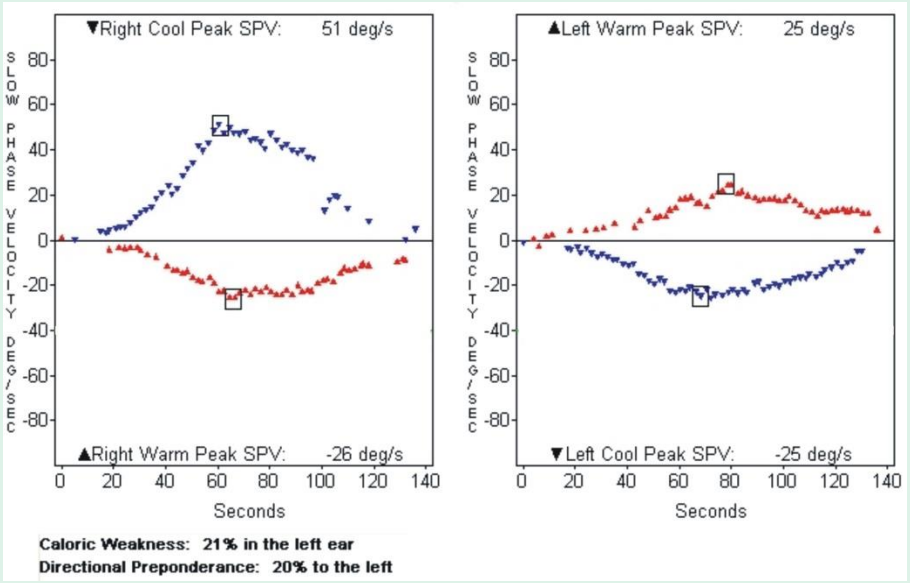
Rule out *tympanic membrane perforation* and *overcalibration*

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)

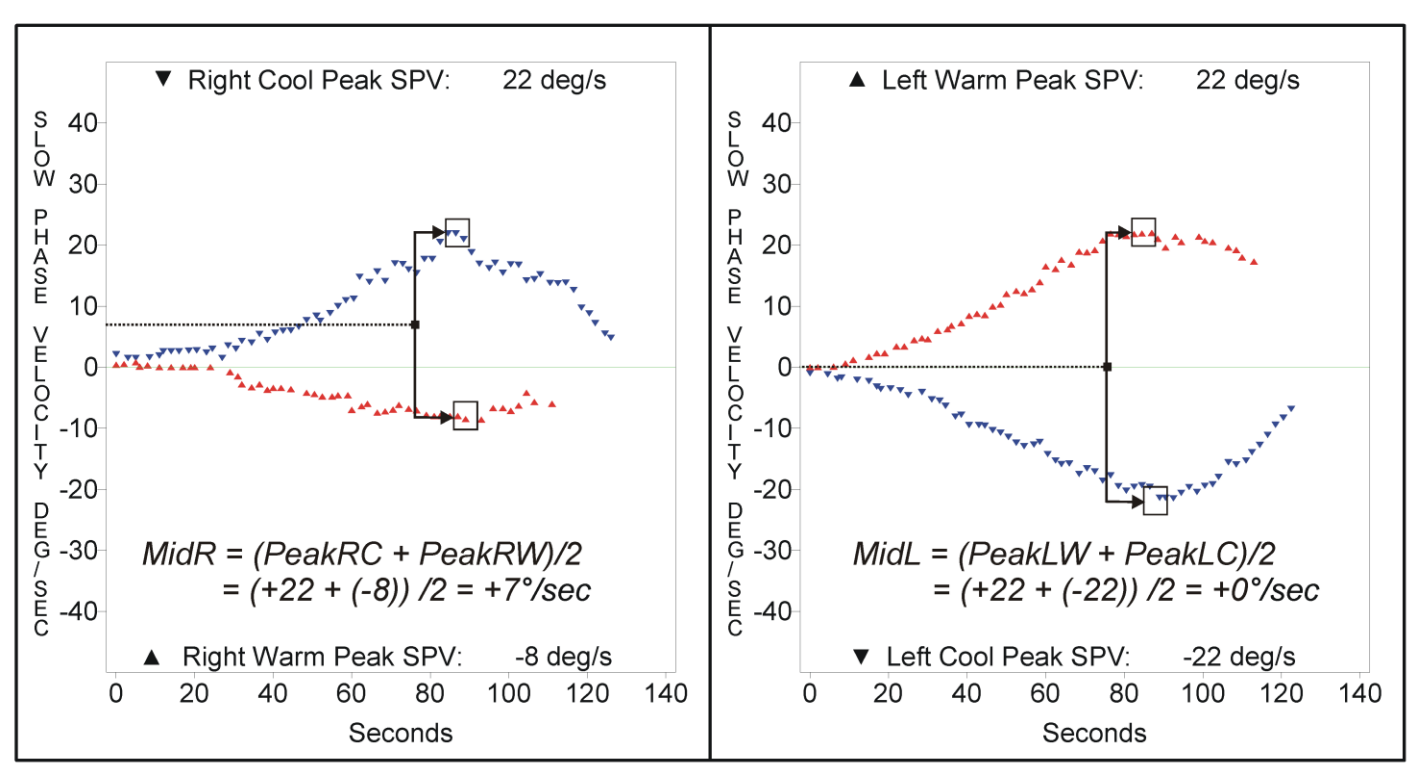
Caloric Test – *Artifacts*





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

Caloric Test – *Artifacts*

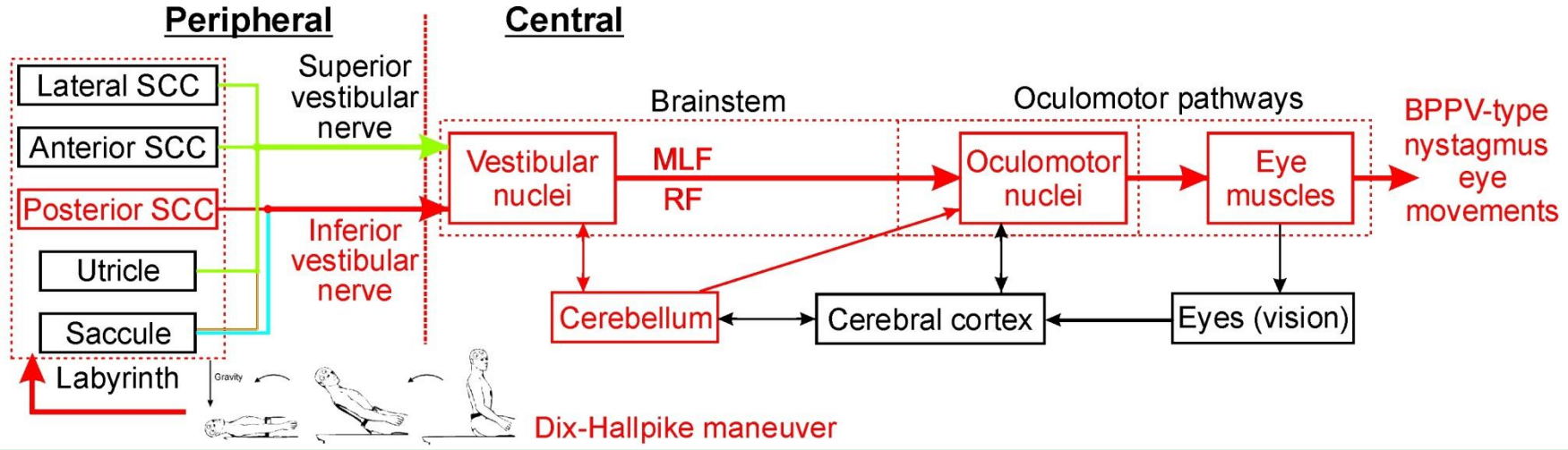


DYNAMIC POSITION TEST

Best Practices in Dix-Hallpike Maneuver

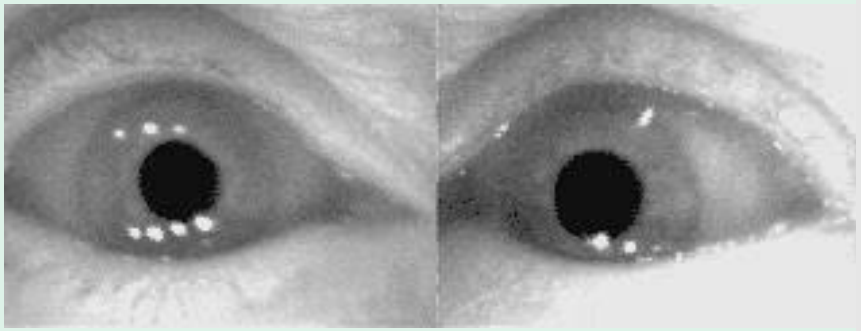
- Turn the head 45 degrees right or left before moving the patient to avoid false-positive bilateral BPPV
  - No difference which side is done first
- No need to move the patient too vigorously from the sitting to supine position
  - Particles are moved primarily by gravity
- No need to hang the head too far over the edge in the supine position
- When responses are delayed, listen to the patient to determine if you have waited enough time
- Check for possible contraindications
  - Severe neck or back problems/arterial blood supply anomalies

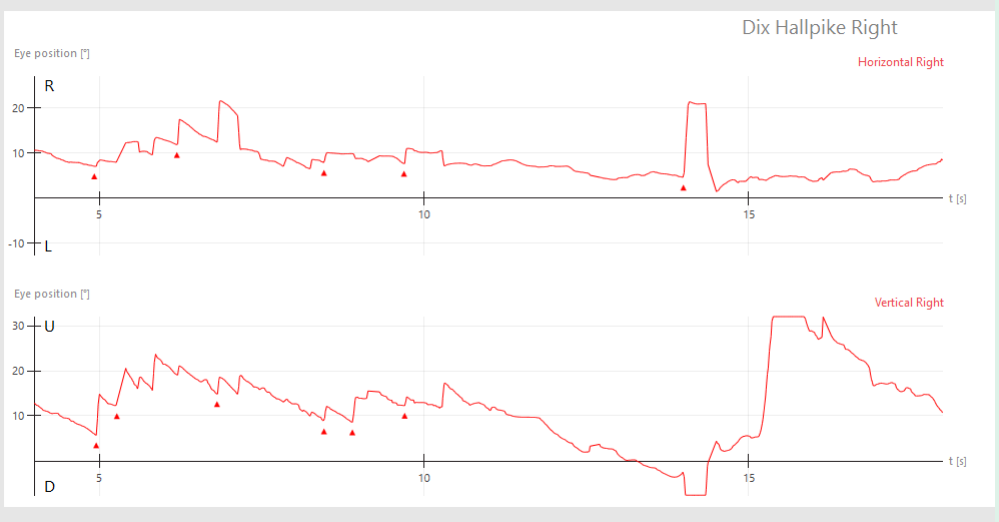
Interpretation of Dix-Hallpike Maneuver



- Dix-Hallpike or sidelying maneuver
  - Most common finding is a BPPV-type nystagmus (transient torsional-vertical nystagmus with delayed-onset) that localizes to the undermost posterior semicircular canal and inferior portion of vestibular nerve
  - In rare cases, contralateral anterior canal is involved
- Roll maneuver
  - For the diagnosis of lateral canal BPPV

Abnormal Dix-Hallpike – *BPPV-Type Nystagmus*



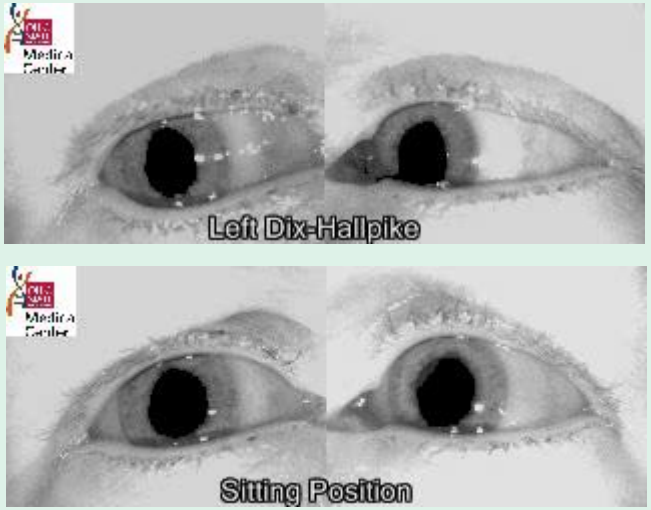


- Torsional–vertical nystagmus (most common type is upbeat with torsion toward the undermost ear indicating posterior canal BPPV)
- Usually delayed onset (~10 seconds)
- Transient (~20 seconds)
- Fatiguable (temporary reduction of nystagmus intensity on repeating the maneuver)
- Subjective sensation of vertigo

General Interpretation of Dynamic Position Test

- What if the patient has static positional nystagmus?
  - Static positional nystagmus – Look for nystagmus that is present as long as head remains in critical position
  - Dynamic positioning nystagmus – Look for transient nystagmus that is provoked by head moving to critical position

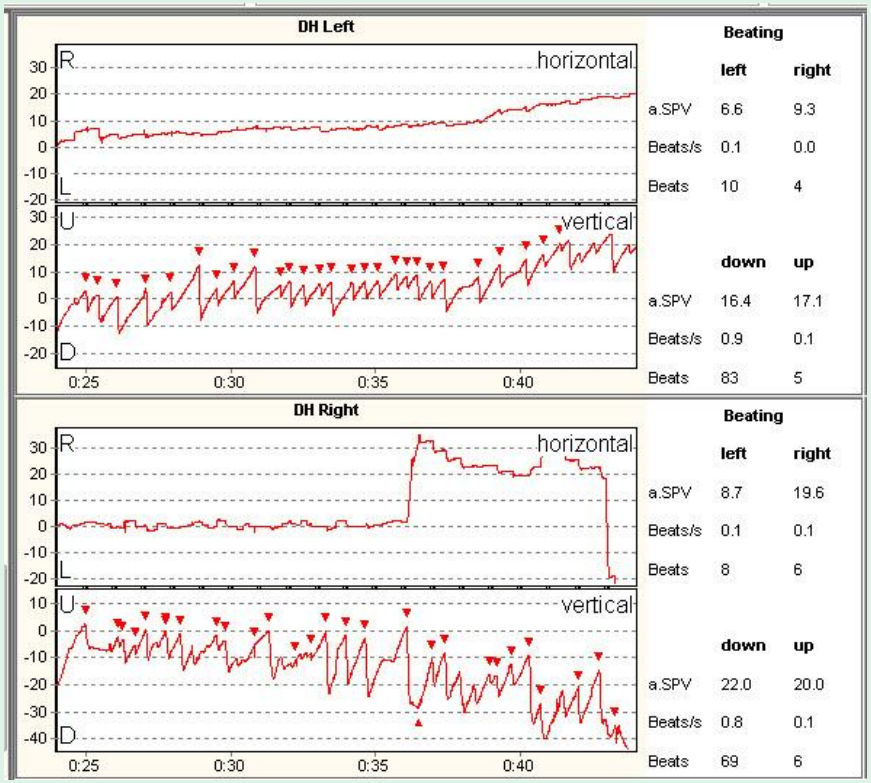
Static nystagmus in the sitting position (similar in all other head positions)

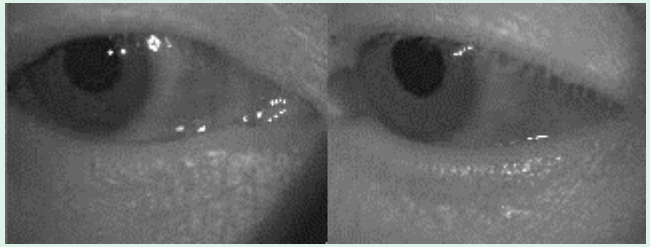


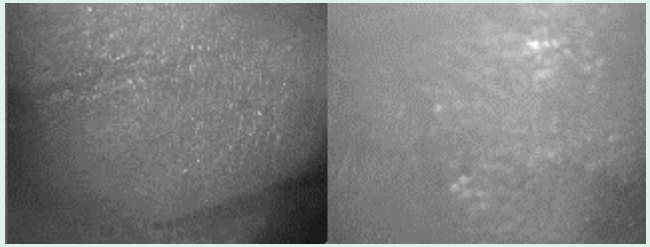
General Interpretation of Dynamic Position Test

- What if the nystagmus has no torsional component?
  - Purely vertical nystagmus – Not BPPV!

Abnormal Dix-Hallpike – *Downbeat Nystagmus*







- Usually bilateral and much longer duration compared to BPPV
- Usually patient does not report true vertigo
- [Denotes a central lesion] in the posterior fossa (same as downbeat nystagmus in gaze testing)
  - Has been reported in bilateral anterior canal BPPV but caution must be taken to rule out central lesions