Identifying Site of Lesion in Vestibular Function Tests

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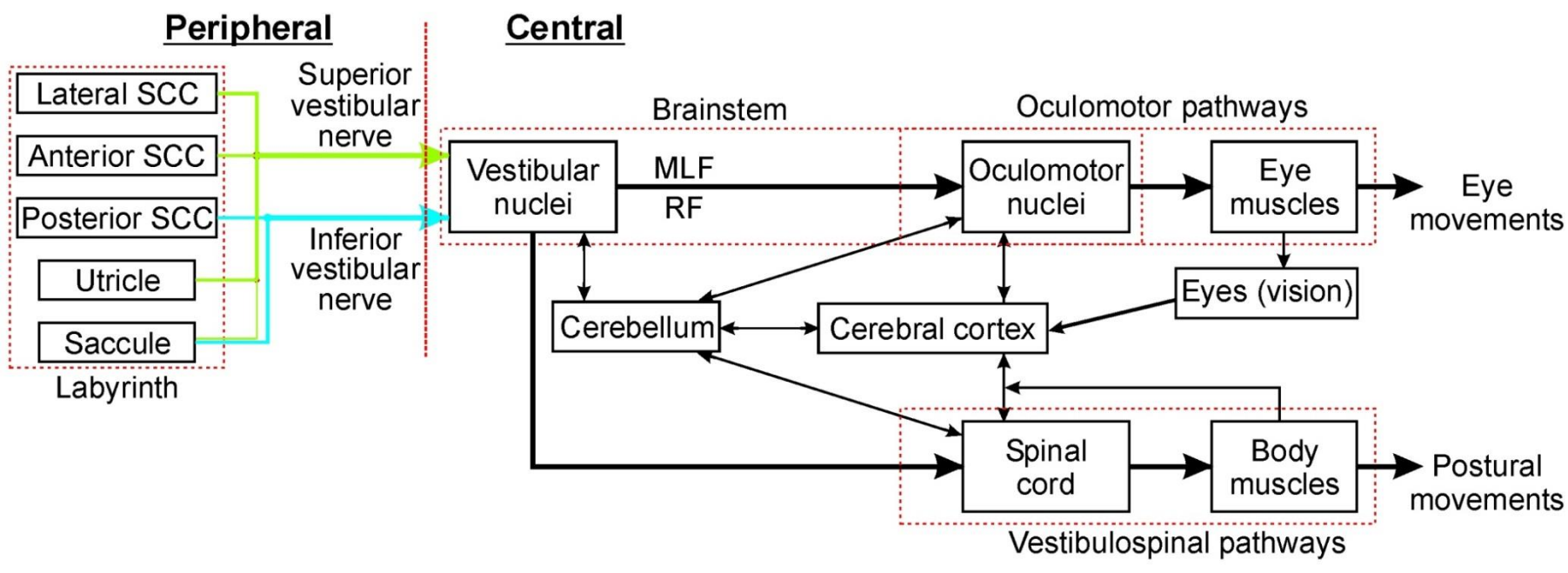
Overview

- Purpose of vestibular function tests
  - Is there a lesion?
  - If yes, can the site and side of lesion be localized?
- Traditional vestibular function tests (ENG/VNG, rotation chair, active rotation) fail to provide adequate answer to the above questions in about 60% of the dizzy patients
- Can recent developments in vestibular testing such as video head impulse test (vHIT) or vestibular evoked myogenic potentials (VEMP), provide more accurate information about the site and side of lesion?

Anatomical Sites Involved in Vestibular Tests

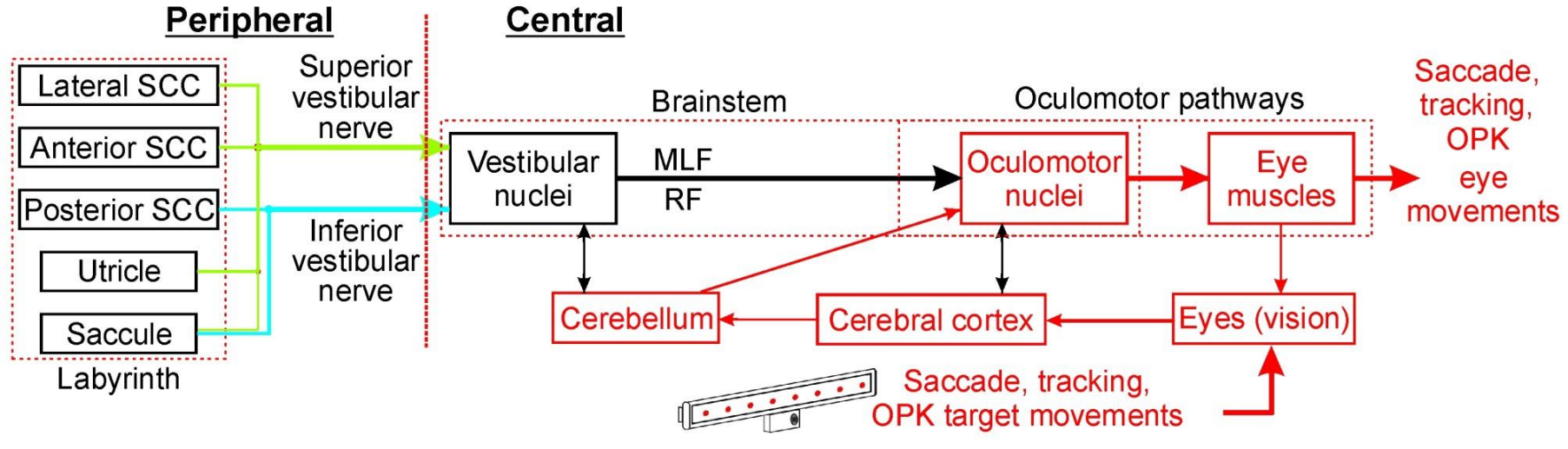


- Vestibular tests evaluate VOR (VNG, rotation tests, vHIT), VSR (posturography), or a combination of both (VEMP)
  - No direct access to the labyrinth or vestibular nerve
  - Peripheral → Labyrinthine structures and two branches of vestibular nerve from the end organ to brainstem → Otologic disease?
  - Central → All structures beyond the root entry zone of vestibular nerve including the vestibular nuclei → Neurologic disease?

Differentiating Peripheral vs Central Lesions

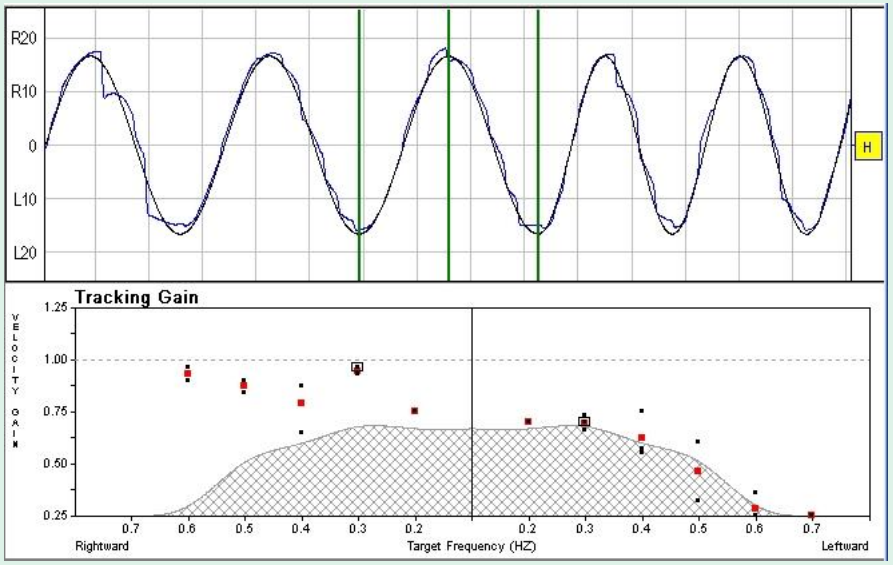
- Exhaustive search for central lesions
  - Oculomotor tests in ENG/VNG, but currently not able to identify every possible central lesion
- Subtracting out central pathways through repeated stimulations
  - Unilateral weakness in the caloric test (subject to caloric test limitations)
- Differentiate based on response characteristics (frequency/velocity/latency)
  - Oculomotor responses are much slower than vestibular responses
    - Hair cell response characteristics in vHIT or BPPV-type eye movements in Dix-Hallpike

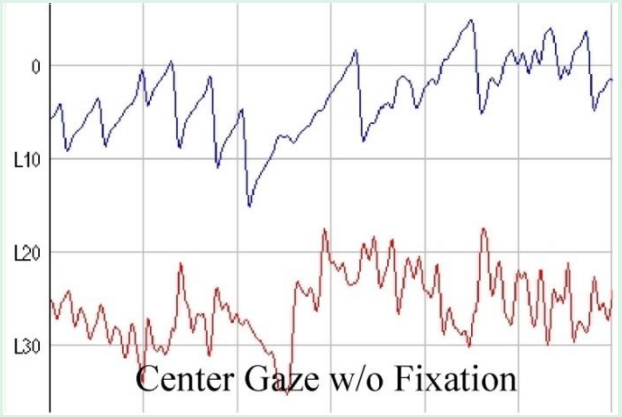
Site of Lesion in VNG/ENG Oculomotor Tests



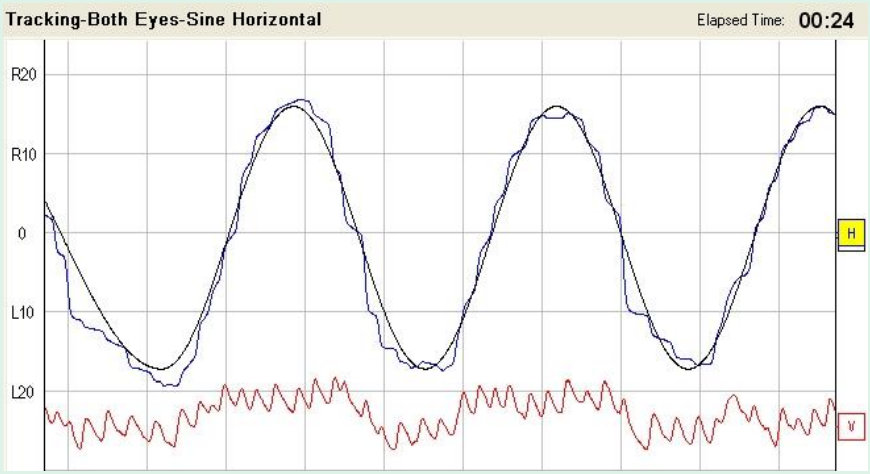
- Tests of oculomotor function (with fixation)
  - Saccade (fast eye movements)
  - Tracking (slow voluntary eye movements)
  - Optokinetic (reflexive eye movements but the test performed as a part of ENG/VNG is not a true test of optokinetic pathways)
  - With very few exceptions (one?), abnormalities 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

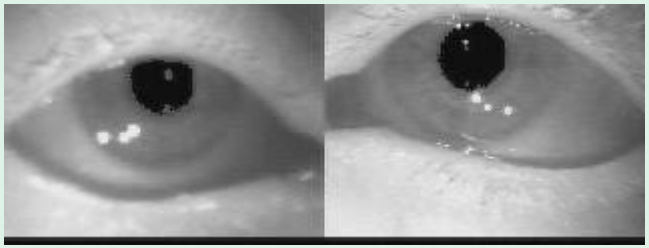
Non-Central Finding in Oculomotor Tests



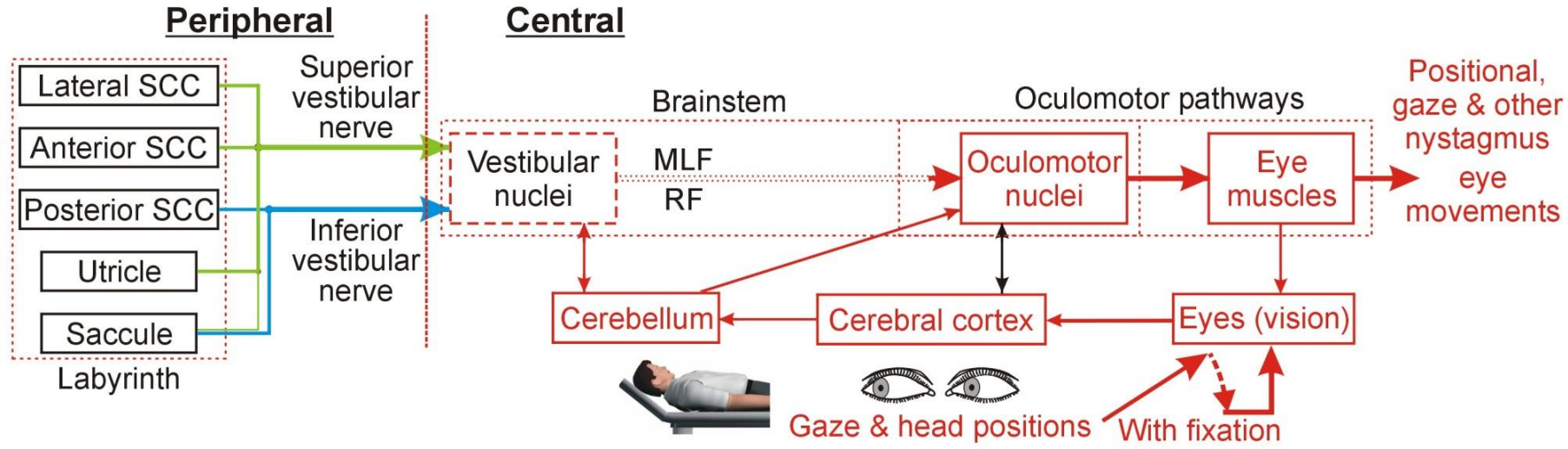


- Borderline unilateral defective tracking caused by strong spontaneous nystagmus (in the direction of fast phases)
  - Effect of superimposed nystagmus and not abnormal tracking



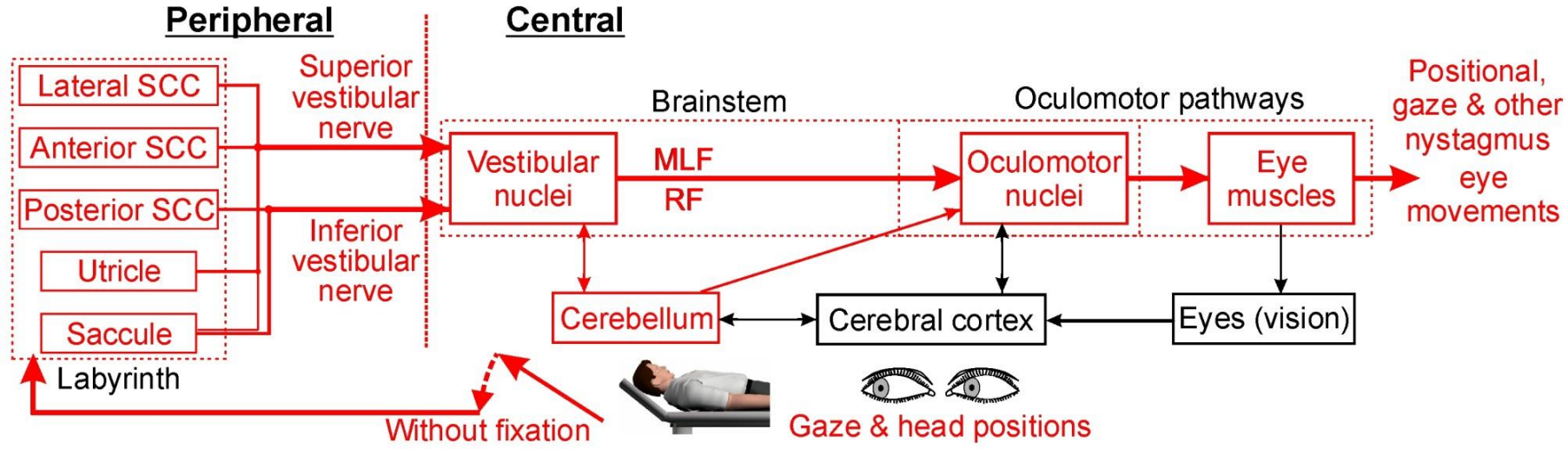


Site of Lesion in VNG/ENG Gaze Stabilization Tests



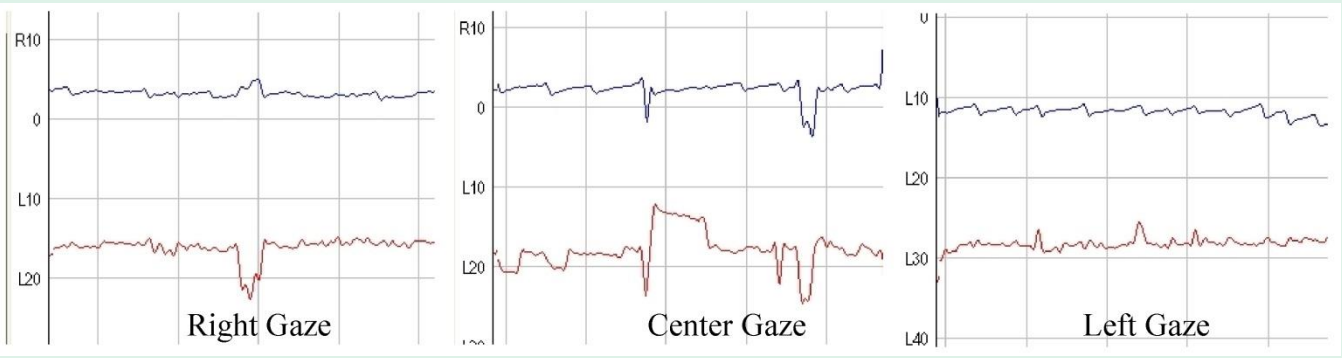
- Tests of gaze stabilization with fixation
  - Gaze test (effect of gaze position on presence/characteristics of nystagmus)
  - With very few exceptions, abnormalities in the gaze test with fixation indicate a central finding

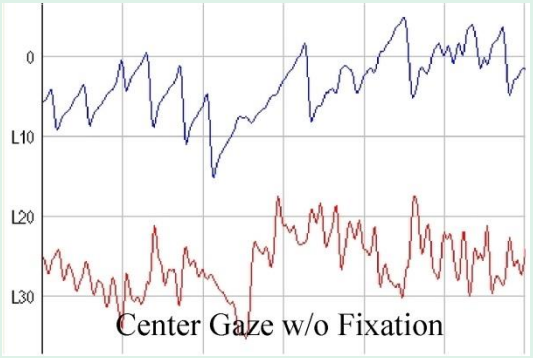
Site of Lesion in VNG/ENG Gaze Stabilization Tests



- Tests of gaze stabilization without fixation
  - Spontaneous nystagmus test (recording eye movements in the primary gaze position with and without fixation)
  - Static position test (effect of head position on presence/characteristics of nystagmus)
  - Abnormalities in gaze stabilization tests without fixation are typically non-localizing but can support localizing findings in other vestibular tests
  - Gaze stabilization tests with fixation provide hard, localizing findings but without fixation, the findings are often non-localizing
  - About 15% of dizzy patients will have abnormal findings in gaze stabilization tests

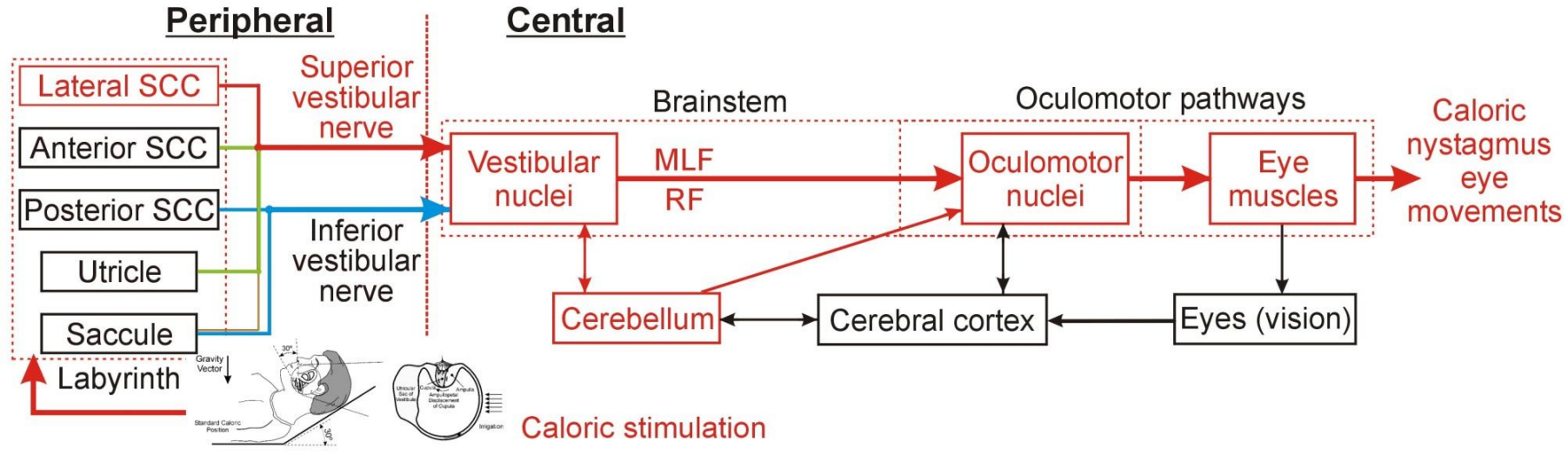
Non-Central Findings in Gaze Stabilization Tests





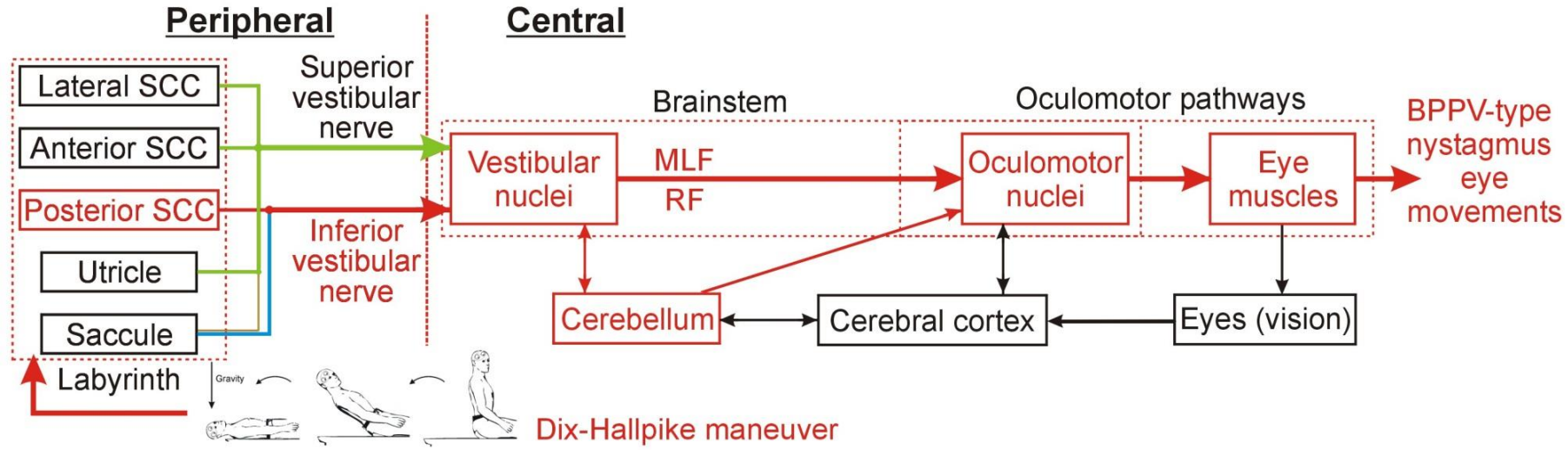
- When unilateral gaze nystagmus is observed with fixation, observe the response without fixation
- If intensity increases significantly, it is not gaze-evoked nystagmus! It is spontaneous nystagmus (usually follows Alexander's law)

Site of Lesion in VNG/ENG Caloric Test



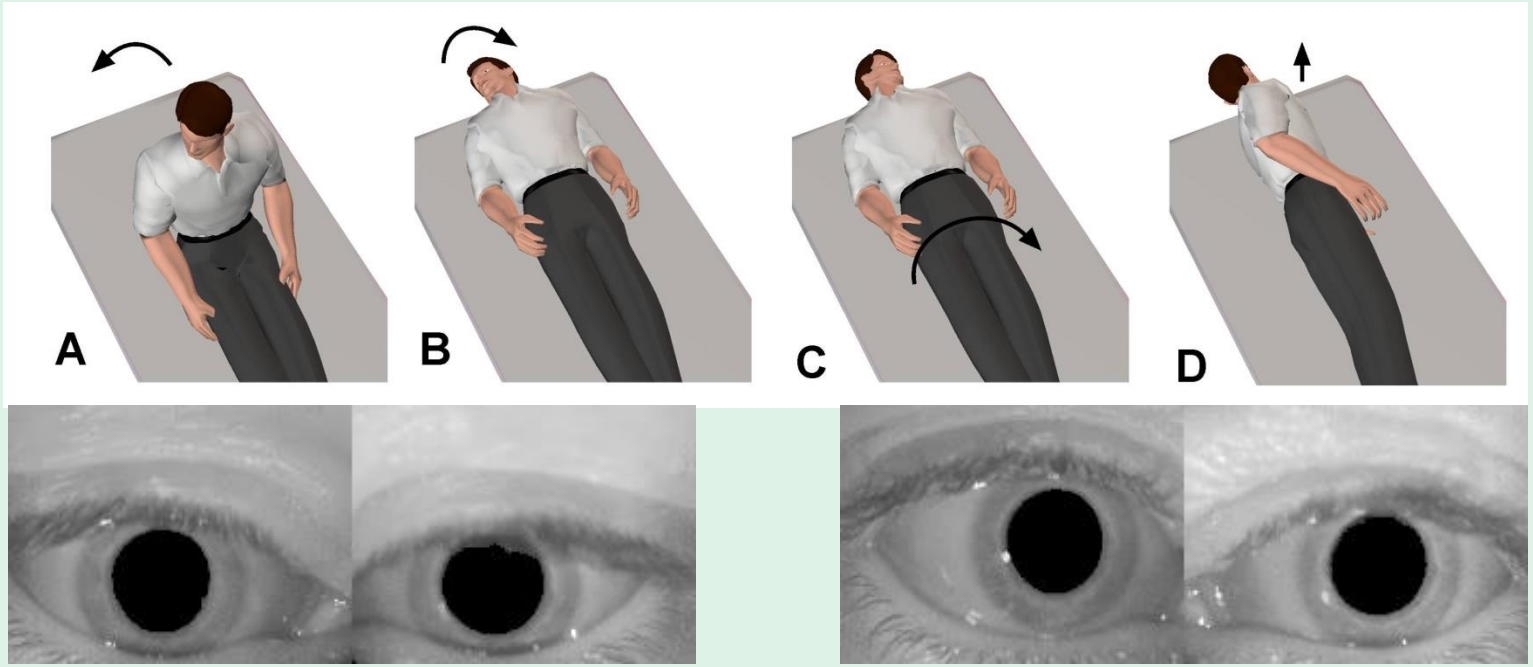
- Test of lateral canals and the superior portion of vestibular nerve
  - Unilateral weakness (canal paresis) indicates a peripheral vestibular lesion involving the lateral (horizontal) canal or its afferent pathways on the side of the weaker response (the involved pathway extends from the end-organ to the root entry zone of the vestibular nerve in the brain stem)
  - Other abnormalities are either non-localizing (directional preponderance/ bilateral weakness) or central (hyperactive/failure of fixation suppression)
  - Caloric testing provides often unique hard localizing findings (abnormal in ~20% of dizzy patients)

Site of Lesion in VNG/ENG Dynamic Position Tests



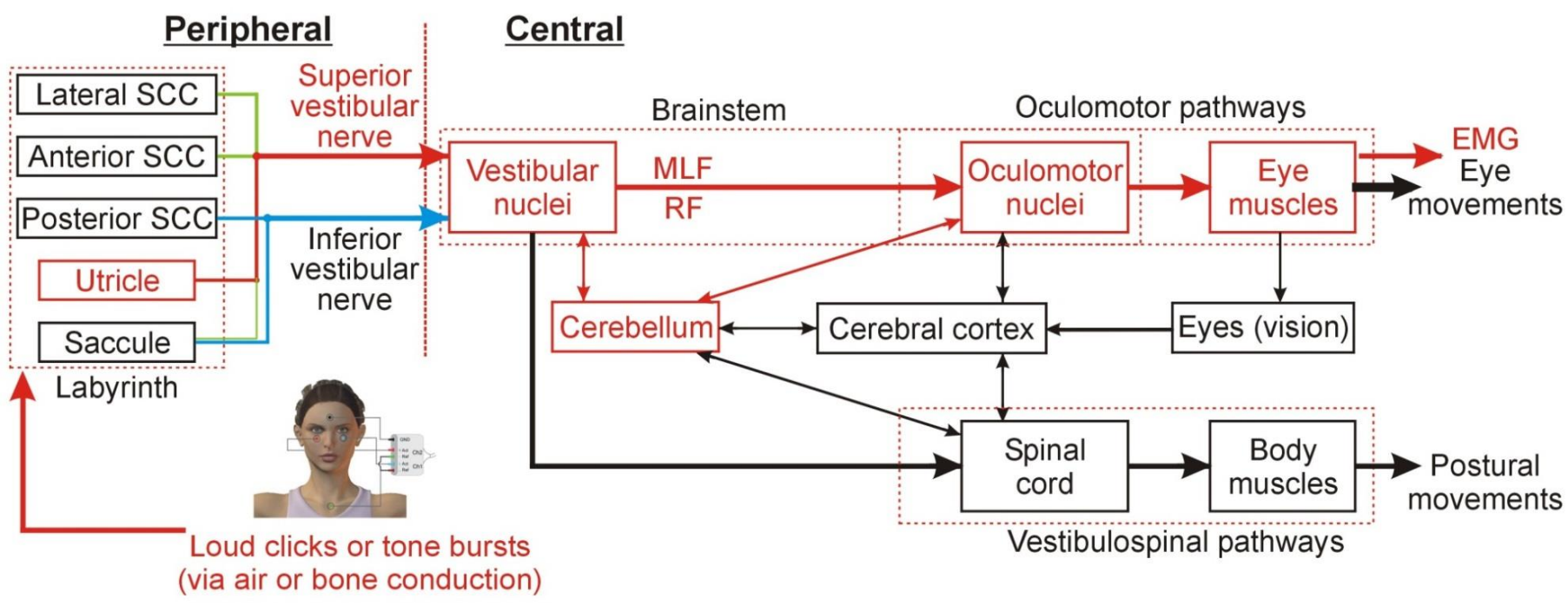
- Dix-Hallpike or sidelying maneuver
  - Most common finding is a BPPV-type nystagmus (transient torsional-vertical nystagmus with delayed-onset) that localizes to the undermost posterior semicircular canal and inferior portion of vestibular nerve
- Roll maneuver
  - For the diagnosis of lateral canal BPPV
- Dynamic position tests are the definitive diagnostic tests for BPPV (abnormal in ~20% of dizzy patients)

Non-Peripheral Findings in Dynamic Position Tests



- Some patients exhibit repeated reversal of nystagmus direction during canalith repositioning therapy (Epley's maneuver), which has been associated with unsuccessful treatment outcomes
- When repositioning maneuvers are unsuccessful (Intractable BPPV), non-peripheral causes should be ruled out
  - Intracranial, vascular, metabolic abnormalities can mimic BPPV

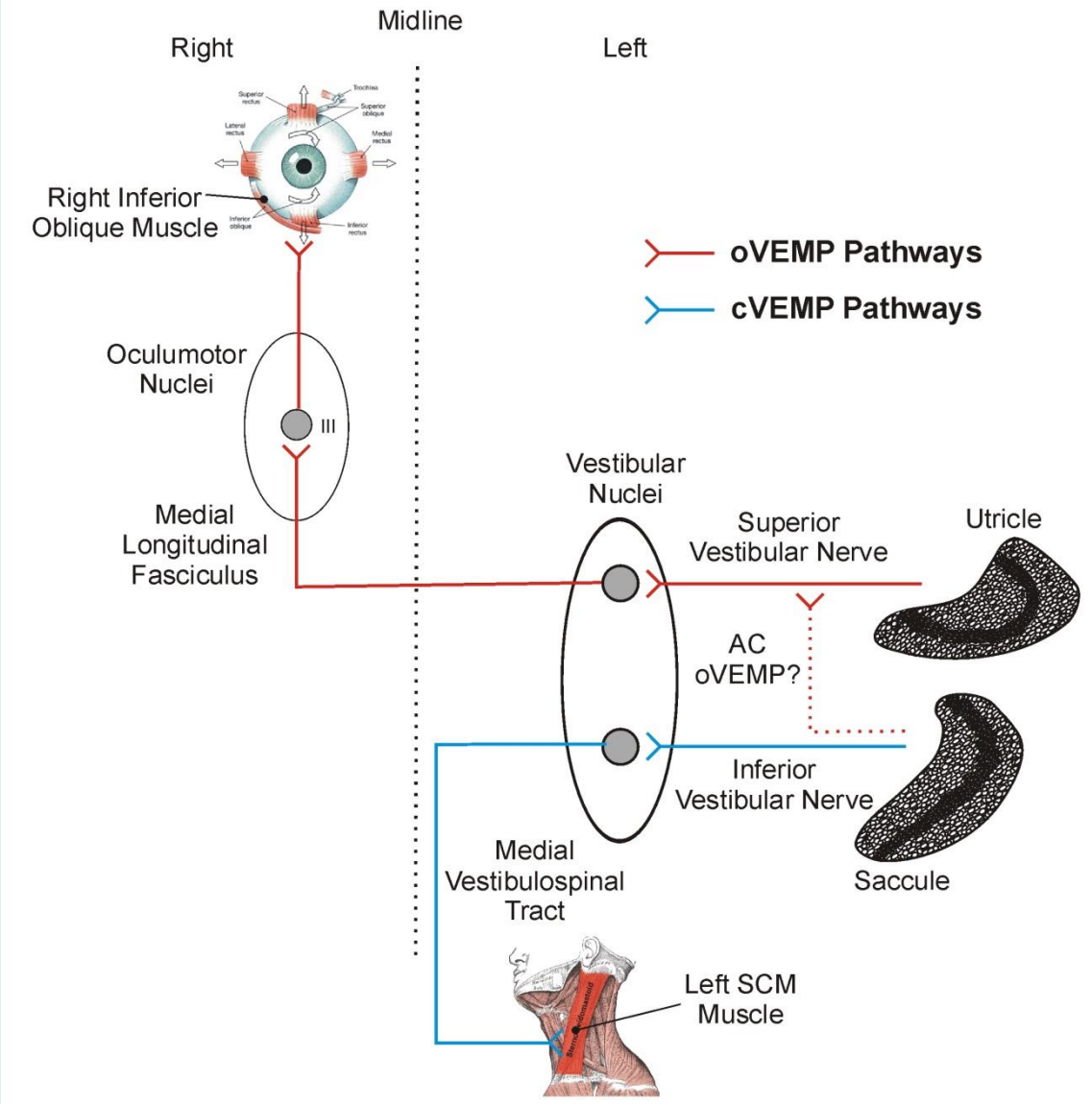
VEMP – *Definition*



- Short-latency electromyographic (EMG) potentials evoked in response to high-level acoustic stimuli
- Most common recording sites:
  - Neck/sternocleidomastoid (SCM) muscle – Cervical VEMP or cVEMP
  - Extraocular/inferior oblique muscle – Ocular VEMP or oVEMP

VEMP – *cVEMP and oVEMP Pathways*

- cVEMP and oVEMP are NOT the same test!
  - Not possible to differentiate between utricular or saccular responses based on the type of stimulus *BUT* differentiation based on motor projections is possible
  - Saccular neurons have a strong projection to neck muscles but weak projection to eye muscles
  - Utricular neurons have a strong projection to eye muscles but weak projection to neck muscle



VEMP – *Response Parameters*

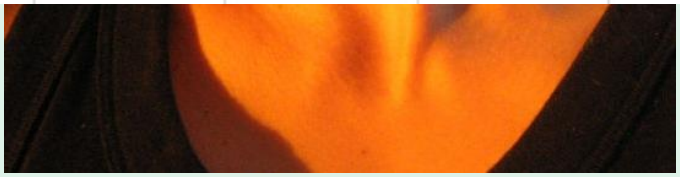
- Presence – Ability to produce an identifiable response at any stimulus type and level
- Latency – Time of positive and negative peaks measured from the onset of stimulus (p1 and n1 in milliseconds)
- Amplitude – Difference between positive and negative averaged EMG levels (p1-n1 in microvolt)
  - Absolute amplitudes of p1 and n1 measured from 0 baseline can also be useful
- Threshold – Minimum sound intensity level to produce an identifiable VEMP response (usually in dB nHL, dB SPL, or dB FL)
- Asymmetry ratio – Normalized difference between right and left amplitudes (in percent)

$$\text{Asymmetry Ratio} = \frac{\text{Amplitude Right} - \text{Amplitude Left}}{\text{Amplitude Right} + \text{Amplitude Left}} * 100$$

Amplitude and latency parameters are derived by averaging values from 2 or 3 trials

Site of Lesion in VEMP Tests – *Central*

- Prolonged latencies usually indicate a central lesion
  - cVEMP latencies are affected by the distance of the electrode from the motor point of the muscle (motor point is usually around the upper 1/3 of the muscle at length about 4” below the mastoid)
  - Sometimes when P1/N1 is absent, secondary waves are misinterpreted as VEMP response



Site of Lesion in VEMP Tests – *Peripheral*

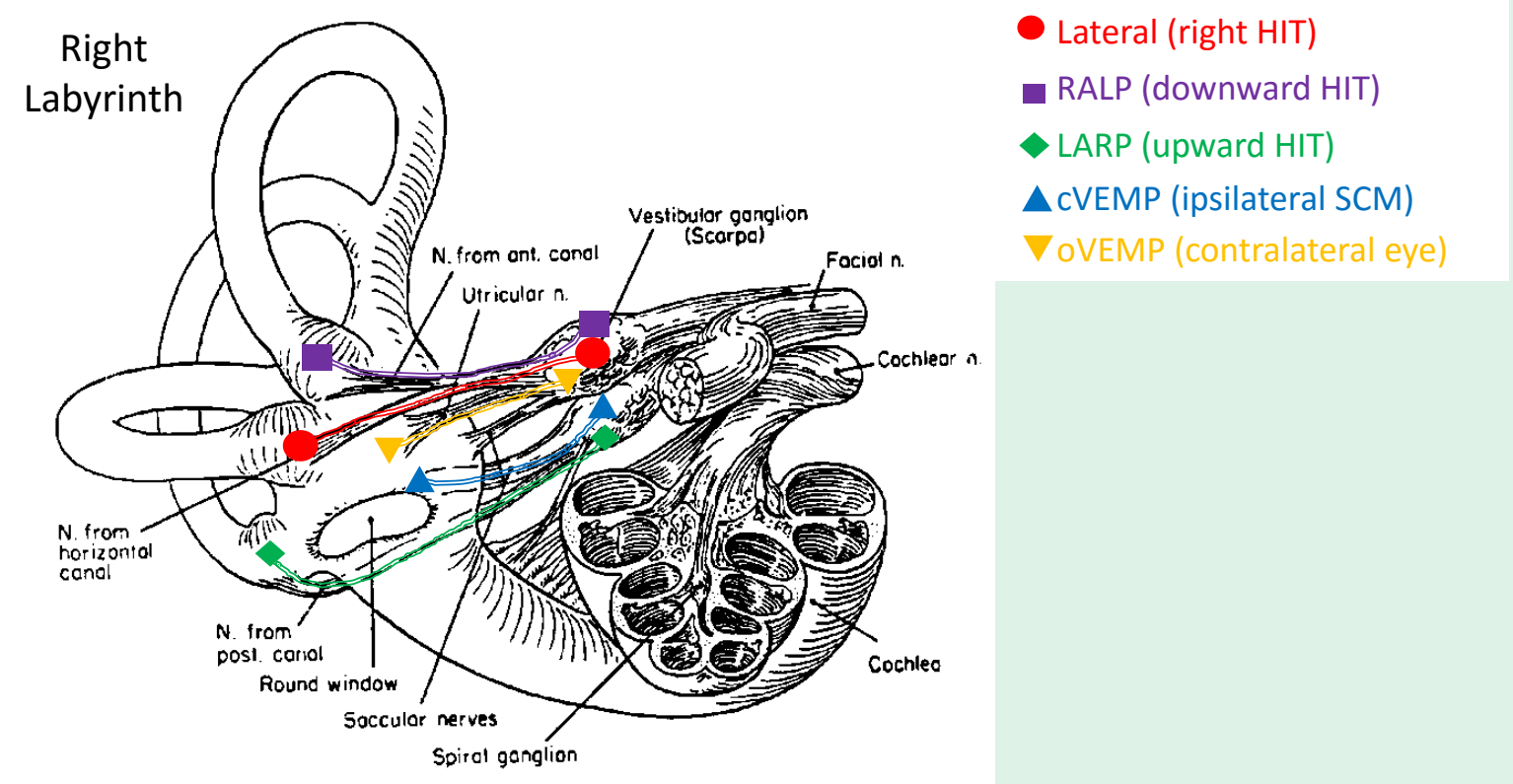
- Low thresholds, elevated amplitudes, or elevated asymmetries usually indicate a peripheral lesion
- In vestibular neuritis, can determine involvement of different vestibular nerve branches
  - Superior branch – Abnormal oVEMP
  - Inferior branch – Abnormal cVEMP
- In SCD, can determine the side
  - Low threshold in air-conducted cVEMP
  - Elevated n1-p1 or n1 amplitude in air-conducted oVEMP (Zuniga et al., 2013)
  - Presence of response at high-frequency (4k) air-conducted oVEMP (Manzari et al., 2013)

Site of Lesion in Video Head Impulse Test

- Presence of abnormal catch-up saccades (overt or covert) denotes a peripheral vestibular lesion involving the semicircular canal or its afferent neural pathway on the side of head impulse
  - Normal individuals may have catch-up saccades but abnormal catch-up saccades can be identified based on their direction, timing, velocity, and consistency
  - VOR gain (slow eye movement / head movement) can be used to support abnormal HIT results

Site of Lesion in New Vestibular Tests

- Combination of vHIT, cVEMP, and oVEMP results provides a complete evaluation of the labyrinth and both branches of vestibular nerve
  - Caloric testing adds low-frequency evaluation of lateral canals and their afferent neural pathways



Identifying Site of Lesion

SITE	Lateral HIT	Vertical HIT (RALP/LARP)	cVEMP	oVEMP
Healthy Subject	Within normal limits	Within normal limits	Within normal limits	Within normal limits
Lateral Canal	Abnormal for impulses toward side of lesion	Within normal limits	Within normal limits	Within normal limits
Anterior Canal	Within normal limits	Abnormal for downward impulses with the head turned away from side of lesion	Within normal limits	Within normal limits
Posterior Canal	Within normal limits	Abnormal for upward impulses with the head turned toward side of lesion	Within normal limits	Within normal limits
Utricle	Within normal limits	Within normal limits	Within normal limits	Abnormal recordings from the eye muscle away from side of lesion
Saccule	Within normal limits	Within normal limits	Abnormal recordings from the neck muscle toward side of lesion	Within normal limits
Superior Vestibular Nerve	Abnormal for impulses toward side of lesion	Abnormal for downward impulses with the head turned away from side of lesion	Within normal limits	Abnormal recordings from the eye muscle away from side of lesion
Inferior Vestibular Nerve	Within normal limits	Abnormal for upward impulses with the head turned toward side of lesion	Abnormal recordings from the neck muscle toward side of lesion	Within normal limits
Total Unilateral Vestibular Loss	Abnormal for impulses toward side of lesion	Abnormal for downward impulses with the head turned away from side of lesion	Abnormal recordings from the neck muscle toward side of lesion	Abnormal recordings from the eye muscle away from side of lesion

Summary

- New vestibular tests have the potential to provide more specific information about different structures within the vestibular system
- More widespread clinical studies are needed to verify and validate the new methods