Vestibular Input-Semicircular Canals
Detect high velocity and frequency angular head accelerations
Stabilize gaze during impulsive head movements
Prevent oscillopsia by minimizing retinal slip

Ewald’s Laws
1st Law- Slow phase eye movement in the direction of endolymph flow in the plane of canal(s) stimulated
2nd Law- Ampulopetal flow is excitatory and ampullofugal flow inhibitory in the lateral canals
3rd Law- Ampullofugal flow is excitatory and ampullofugal flow inhibitory in the vertical canals

Physiologic Nystagmus

Pathologic Nystagmus- Acute

Pathologic Nystagmus-Early Compensation

Pathologic Nystagmus-
Partial Compensation
Pathologic Nystagmus—Full Static Compensation

Pathologic Nystagmus—Dynamic Compensation

Vestibular Input—Otolith Organs
Sense transient linear accelerations and stabilize body position
Sense gravity and set background muscle tonus
Contribute to the linear VOR
Ocular counter rolling
Ocular skew

Orientation of Otolith Maculae

Otolith-ocular Reflexes
Linear VOR (LVOR)—linear ocular response to stabilize target on retina during transient linear acceleration in yaw and pitch planes
Ocular counter roll—torsional ocular response to align the horizon on the retina in response to sustained tilt in the roll plane
Tilt-induced skew deviation—disconjugate vertical alignment of the eyes to align the horizon on the retina in response to sustained tilt in the roll plane

Vestibular system: diverse and vital roles
Vestibulo-ocular and spinal input

Visual Inputs
Optokinetic reflex to sense relative visual movement
Smooth pursuit to track desired targets
Saccades to re-fixate on new targets
Normal Oculomotor Function

Abnormal Oculomotor Function

Somatosensory Inputs
Pressure receptors to sense interaction with support surface
Stretch receptors to sense joint alignment and muscle tension

Central Sensory Integration
Compare sensory inputs
Create context-dependent hierarchy
Generate appropriate command to motor system for posture control

Vestibular system: diverse and vital roles
Vestibulo-cortical-hippocampal input:
Spatial memory
Spatial navigation

Motor Output
Pyramidal
Extrapyramidal
Multisegmental reflex loops
Musculoskeletal conditioning

Movement Strategies
Ankle strategy
Hip strategy
Step strategy
Summary
Balance and gaze stability rely on a combination of sensory inputs, central integration and motor output
The VOR stabilizes gaze during rapid head movement
The VSR helps stabilize posture during transient linear accelerations or gravity
Adaptive plasticity and sensory substitution are critical to compensation following vestibular injury

History Taking

Evaluation of the Dizzy Patient
History (70%)
Physical Exam (10-20%)
Laboratory Tests (10-20%)

How to Obtain the History
Structured questionnaire mailed to the patient
Personal interview using the questionnaire as a guide

Key Historical Points
Presence or absence of vertigo
Time course of the sensation
Accompanying symptoms/signs
Relation to movement/head position
Differentiation of Central From Peripheral Dizziness

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Peripheral</th>
<th>Central</th>
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<tbody>
<tr>
<td>Hallucination of movement</td>
<td>Definite</td>
<td>Less definite</td>
</tr>
<tr>
<td>Onset</td>
<td>Usually paroxysmal</td>
<td>Seldom paroxysmal</td>
</tr>
<tr>
<td>Intensity</td>
<td>Usually severe</td>
<td>Seldom severe</td>
</tr>
<tr>
<td>Duration</td>
<td>Seconds to hours</td>
<td>Weeks to months</td>
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<tr>
<td>Influenced by head position</td>
<td>Frequently</td>
<td>Seldom</td>
</tr>
<tr>
<td>Nystagmus</td>
<td>Present</td>
<td>Present or absent</td>
</tr>
<tr>
<td>Autonomic nervous system symptoms</td>
<td>Definite</td>
<td>Less definite or absent</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>Frequently present</td>
<td>Seldom present</td>
</tr>
<tr>
<td>Deafness</td>
<td>Frequently present</td>
<td>Seldom present</td>
</tr>
<tr>
<td>Disturbances of consciousness</td>
<td>Absent</td>
<td>More frequently present</td>
</tr>
<tr>
<td>Other neurological signs</td>
<td>Usually absent</td>
<td>Frequently present</td>
</tr>
</tbody>
</table>

The Million Pound Question

QUESTION- Do you get dizzy just rolling over in bed?

ANSWER?

The Million Pound Question

QUESTION- Are you light sensitive during your dizzy spell?

ANSWER?
The Million Pound Question
QUESTION- Does one ear feel full before or during your dizzy attack?

ANSWER?
The Million Pound Question

QUESTION- Does a loud sound make you dizzy or make your world jiggle?

ANSWER?

The Million Pound Question
QUESTION- Was your first attack severe vertigo lasting hours with nausea and vomiting?

ANSWER?

The Million Pound Question
QUESTION- Are you lightheaded when you get up from a bed or chair for a few seconds?

ANSWER?

The Million Pound Question
Do you pass out completely with your dizziness?

ANSWER?
Predictive Capability of Historical Data for Diagnosis of Dizziness

<table>
<thead>
<tr>
<th>Observed</th>
<th>BPPV</th>
<th>Migraine</th>
<th>Ménière's</th>
<th>Vestibular neuritis</th>
<th>Other vestibular</th>
<th>Other CNS</th>
<th>Other miscellaneous</th>
<th>Predicted</th>
<th>Percent correct (%)</th>
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<td>3</td>
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<td>4</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
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<td>49</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<td>Vestibular neuritis</td>
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<td>1</td>
<td>1</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>62.5</td>
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<tr>
<td>Other vestibular</td>
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<td>2</td>
<td>1</td>
<td>26</td>
<td>2</td>
<td>0</td>
<td>78.8</td>
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<td>Other CNS</td>
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<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>26</td>
<td>2</td>
<td>66.7</td>
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<tr>
<td>Other miscellaneous</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>44</td>
<td>86.3</td>
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<tr>
<td>Overall percentage (%)</td>
<td>31.6</td>
<td>17.0</td>
<td>14.2</td>
<td>6.9</td>
<td>8.1</td>
<td>9.2</td>
<td>13.0</td>
<td>83.7</td>
<td></td>
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</tbody>
</table>
The Ten Minute Exam of the Dizzy Patient

Components of the Physical Exam
VOR exam- nystagmus, head impulse, head heave, headshake, dynamic visual acuity, ocular torsion, ocular skew
VSR exam- tandem Romberg, foam Romberg, step test
Central OM exam- gaze, pursuit, saccade, fixation suppression
Posture
Gait

Office Exam Tools

New examination tool for nystagmus: the take-away “Michael’s glasses”
Strupp et al. Neurology (2014)

Remote Eye Movement Recording

Spontaneous Nystagmus
Eyes open versus Frenzel lenses
Direction-fixed versus changing
Pendular versus jerk nystagmus
Saccadic intrusions

Alexander’s Law
1st degree nystagmus- present only in gaze towards fast phase
2nd degree nystagmus- present in neutral gaze and stronger in gaze towards fast phase
3rd degree nystagmus- present in all gazes, strongest in gaze towards fast phase
Congenital Nystagmus
Present since birth/early childhood
Horizontal direction changing
Pendular and jerk waveform
Null point
Dampens with convergence

Other Forms of Central Spontaneous Nystagmus
Downbeat
Upbeat
See-saw
Convergence-retraction
Square wave
Ocular flutter
Opsoclonus

Gaze Nystagmus
Direction changes with direction of gaze
Exponentially-decreasing waveform
Sustained

Forms of Gaze-evoked Nystagmus
Horizontal in lateral gaze
Vertical in up or downgaze
Downbeat in lateral gaze
Dissociated abducting nystagmus in lateral gaze

Smooth Pursuit
Smooth movement
Best corrected vision
Horizontal better than vertical
Abnormalities of Smooth Pursuit
Erratic
Saccadic
Absent
Uni- or bi-directional

Saccadic Pursuit

Optokinetic Reflex
  Characteristics
Full field retinal stimulation
Optimal function with large slow repetitive target motion
Augments low-frequency VOR signal
Primitive non-voluntary reflex

Saccades
Conjugate
Accurate
Fast
Minimal delay

Saccadic Eye Movements
Saccadic dysmetria (dorsal vermis/fastigial nuclei)
Post-saccadic drift (flocculus)
Saccadic slowing (age, medications, brainstem lesions, oculomotor lesions)
Delayed saccades (age, attention, oculomotor apraxia, Parkinson’s Disease)
Fixation suppression
Rotate chair and observe nystagmus
Focus on finger moving with patient and observe for nystagmus
Failure implies flocculus lesion

Head Impulse Test (HIT)
Move from side to center
Focus on target
Look for corrective saccade
Can be unilateral or bilateral

Headshake Test
2 Hz for 20 seconds
Use Frenzel lenses
Observe for post headshake nystagmus
Usually beats towards stronger ear
Observe for cross-coupling and reversal

Dynamic Visual Acuity Test
Normal- <3 line decrease in acuity during 2 Hz headshake
Deficient VOR- 3 or more line decrease in acuity

Ocular Torsion Test
Move patient’s head slowly in roll plane
Observe eyes for counter-rolling
Symmetric, asymmetric, absent
Implies presence or absence of otolith (utricular) ocular reflex (OOR)
**Vestibular Skew Deviation**

Observe eyes for vertical alignment
Unilateral otolith loss- ipsilateral eye down, contralateral eye up
May be confused with central skew deviation or strabismus

**Position Testing**
Dix-Hallpike test- observe latency, duration, fatigue, direction, reversal
Static positional- use Frenzel lenses

**Right Posterior Canal BPPN**

**Lateral Canal BPPN**
Triggered by side-lying or Dix-Hallpike test
Canalithiasis- transient geotropic horizontal (downward ear stronger)
Cupulolithiasis- prolonged ageotropic horizontal (downward ear weaker)
Treated with log roll or Gufoni maneuver

**Anterior Canal BPPN**
Very rare
Downbeat ageotropic torsional nystagmus (upward ear involved)
Many cases are posterior canal BPPN with debris on non-ampullated end
Treatment- modified CRP (true Ant BPPN) or Epley (atypical Post BPPN)
**Additional Tests**

Pneumatic otoscopy  
Sound stimulation  
Valsalva  
Hyperventilation  
Mastoid oscillation  

Hyperventilation-induced Nystagmus  
Nystagmus induced with vigorous breathing  
Fast phase directed towards diseased ear (irritative)  
Seen in MS and lesions of the VIII nerve  
Recently in post-gamma knife for vestibular schwannoma  

Vibration-Induced Nystagmus  
Under Frenzel lenses  
Vibrate at Fz and behind both ears  
Nystagmus usually towards the intact (stronger) ear  

**Limb Testing**  
Finger-nose-finger  
Heel-shin  
Rapid alternating motion  
Joint proprioception  
Vibration detection  
Flexibility/strength
Posture and Gait Testing
Romberg EO/EC
Romberg EO/EC on foam
Tandem Romberg
Step test
Gait observation

Fukuda Step Test
Ask patient to march in place eyes closed for 40-50 steps
Observe for rotation in yaw plane
>45 degree deviation - abnormal

Subjective Visual Vertical- “Bucket and Rod”
All-inclusive blank visual surround (bucket)
Linear visual target (rod)
Align target to vertical
Abnormal- >2-3 deg tilt towards side of lesion in acute phase
Adaptation over time in chronic phase

Gait Observation
Path- straight or veering
Stride- normal, shortened, heel strike
Base- normal, wide
Initiation- normal, halting
Rhythm- normal, ataxic
Turns- smooth, festinating
Symptoms/Signs of Peripheral Vestibular Disease
Repeated episodes of vertigo in absence of accompanying neurological complaints
Spontaneous nystagmus-direction fixed, horizontal rotary, suppressed by fixation, normal OM exam, no skew deviation
Positive HIT, PHN, reduced DVA
Positive Dix-Hallpike
Imbalance without ataxia

Symptoms/signs of CNS Disease
Vertigo/dysequilibrium, incoordination with accompanying CNS complaints and inability to stand unassisted
Spontaneous nystagmus- vertical, torsional, direction-changing, enhanced with fixation
Abnormal SP, saccades
Atypical positioning nystagmus
Ataxic gait
Skew deviation
Absent HIT

Peripheral vestibulopathy versus stroke?

HINTS- “Head Impulse Nystagmus Test of Skew”
INFARCT- “Impulse Normal Fast Phase Alternating Refixation on Cover Test”

Newton-Toker DE et al. Stroke 2013;44:1158-1161
SEND HIM ON HOME SAFE
Straight Eyes No Deafness
Head Impulse Misses
One-way Nystagmus
Healthy Otic and Mastoid Exam
Stands Alone Face Even