Vestibular Rehabilitation: 
*Practical Management of the Patient with Dizziness*

Jeff Walter PT, DPT, NCS
Disclosures

• I see patients with vestibular dysfunction, ~40 hours/week, in the following hospital-based settings:
  – Outpatient
  – ER / Acute Care
  – Inpatient Rehabilitation

• I enjoy teaching vestibular rehabilitation courses approximately 20 weekends / year, I have taught courses for 10 years.
Disclosures

• I teach for the following entities Education Resources Inc, Hand-on Seminars, Learning and Training Center, Micromedical Technologies, Select Medical.

• Adjunct faculty at Misericordia University and the University of Scranton

• My background is primarily clinical, not research-based

• Developed www.vestibularseminars.com designed to promote clinician education in the area of vestibular rehabilitation
Suggested Reference: Vestibular Rehabilitation: 3rd edition, 2007 by Susan Herdman PT, PhD
Suggested Reference:
Neurology of Eye Movements: 4\textsuperscript{th} edition (with DVD) by Leigh and Zee
Helpful Website

- [www.dizziness-and-balance.com](http://www.dizziness-and-balance.com) established by Timothy C. Hain MD, a neurologist from Chicago. **Great site for clinician and patient education.**
Vestibular System: Anatomy and Physiology

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Terminology

- **Dizziness?**
  - “a whirling sensation in the head”
  - “giddy”
  - “mentally confused”
  - “off-balance”
Terminology

• **Vertigo**: *false sense of rotation*
• **Oscillopsia**: *gaze instability*
• **Imbalance**: *unsteadiness (observable)*
• **Disequilibrium**: *subjective sense of imbalance (not observable)*
• **Lightheadedness / Presyncope**: *feeling of faintness*
Vestibular System?

• Comprised of
  – vestibule (sensory organ)
  – 8th cranial nerve (vestibular-cochlear)
  – brainstem vestibular nuclei
  – cerebellar pathways
  – vestibulo-ocular reflexes (VOR)
  – vestibulocollic reflexes (VCR)
  – vestibulospinal reflexes (VSR)
Purposes of the Vestibular System

• **Sensory:**
  – *Perception of motion and orientation*
    • Angular acceleration
    • Linear acceleration
    • Position in relation to gravity

• **Motor:**
  – Control of eye movement to permit clear visual image of surrounds
  – Maintenance of equilibrium and desired posture
Canal Orientation
Canal Orientation
(c) Ampulla, sectional view

- Membranous labyrinth
- Endolymph
- Cupula
- Hair cells
- Supporting cells
- Sensory nerve
- Crista
Canals detect *angular acceleration* of the head.

**Diagram:**
- **A:** Beginning of rotation; endolymph stays behind.
- **B:** Rotation maintained; endolymph catches up.
- **C:** Rotation stops; endolymph keeps going.
The membranous labyrinth is seated within a bony shell, with connective tissue providing support.
Summary points: Semicircular canals

- Semicircular canals
  - dilated endings (ampulla) of the canals contain hair cells imbedded within a membranous material (cupula)
  - specific gravity of the cupula is equal to the surrounding endolymph
  - senses *angular acceleration* (change in velocity) through displacement of the cupula
Summary points: Semicircular canals

• Semicircular canal (cont)
  – membranous labyrinth secured within the bony labyrinth by connective tissue
  – canals originate from the utricle
  – orthogonal relationship
Otoconia
(Jang et al 2006)

Young vs Old
Otoconia: Age related degeneration

Middle age vs. Old age
Otoconia: “Linking” Filaments
Age related changes in Otoconia

- Increased variability in size
- Hypertrophy
- Fragmentation
- Fissured
- Pitted
- Weakening of linkages
Otolith organs sense **tilts** and **translations** of the head.
Summary points: Otolith Organs

• Utricle and saccule comprise medial portion of the vestibule

• Each organ contains sensory hair cells imbedded within a membrane with otoconia attached to the:
  ➢ Medial wall of saccule
  ➢ Floor of utricle

• Specific gravity of otoconia is greater than the surrounding endolymph

• Responsive to linear acceleration forces, example: gravity
Next Olympic Heroes

Going For The Gold
Vascular supply

• Originates from the basilar artery (posterior circulation)
• Primary supply for the vestibule is as follows:
  – Basilar → AICA → Labyrinthine artery → Anterior vestibular artery
  – Basilar → AICA → Labyrinthine artery → Common cochlear artery → Posterior vestibular artery
• Anterior vestibular artery nourishes the anterior and horizontal semicircular canals and the utricle.
• Posterior vestibular artery nourishes the posterior semicircular canal and the saccule.
Neural innervation

• Superior portion of VIIIth nerve innervates anterior and horizontal canals and utricle

• Inferior portion of VIIIth nerve innervates posterior canal and saccule
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Physiology

• Vestibulo-ocular reflex (VOR): generates oculomotor responses to stabilize gaze during head motion

• Example:
  – Rotation of head to the right results in leftward compensatory eye movement
VOR with rightward rotation of the head

1. Detection of rotation

2. Inhibition of extraocular muscles on one side.

2. Excitation of extraocular muscles on the other side

3. Compensating eye movement
• **Types of eye movement**

• **Abduction/adduction**

• **Elevation/depression**

• **Torsion**
VOR Physiology (cont)

- Optimal range of the peripheral vestibular system is head motion at
  - frequencies = to .8 to 4 hz
  - velocity > 75 deg/sec to < 350 deg/sec
- Latency of VOR is < 15 msec (vs. 75 msec for visual-mediated eye movements)
- Gaze stability is maintained by the smooth pursuit system at lower frequencies and head velocities motion
Physiology (cont)

• Canal/otolith excitation
  – Spontaneous firing rate is 90 pulses per second
  – Sensitivity to head velocity: 0.5 pulse per degree per second
  – Contralateral vestibular nerve inhibition is driven to 0 spikes/sec for head velocities of >180deg/sec.
  – Capacity to stimulate nerve is far greater than capacity to inhibit (Ewald’s 2nd Law)
Example of Physiological Response

Neutral Head Position

100 spikes/sec. 100 spikes/sec.

Acute Left Vestibulopathy (neutral head position)

100 spikes/sec. 90 spikes/sec.
Nystagmus

Left

Right
Canal Specific Eye Movements: Slow Phase Component of VOR

- RPC = right posterior canal
- RHC = right horizontal canal
- RAC = right anterior canal
- LPC = left posterior canal
- LHC = left horizontal canal
- LAC = left anterior canal

\[
\begin{align*}
RAC + LAC &= \uparrow \\
RAC + RPC &= \nearrow \\
RAC + RPC + RHC &= \nearrow \rightarrow
\end{align*}
\]

Central Patterns

Peripheral Pattern
Questions

• Name a canal which is capable of producing downbeating nystagmus (upward slow phases)? _________________

• Name two forms of nystagmus which are uncommon with peripheral vestibular dysfunction: _________ or ___________
Physiology (cont)

• “Other” ocular mobility and stability systems
  – **Nystagmus (quick phases):** resets the eyes during prolonged rotation and directs gaze towards the oncoming visual scene
  – **Smooth pursuit:** maintains image of a small moving target on the fovea (fovea = the center of the retina, the region of highest visual acuity).
  – **Saccades:** rapid eye movement that brings the object of interest onto the fovea
  – **Optikinetic:** generates eye movements in response to sustained rotations
  – **Visual fixation:** holds the image of a stationary object on the fovea by minimizing ocular drifts
  – **Vergence:** moves the eyes in opposite directions so that images are held simultaneously on both foveae
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Which individual lacks vestibular function?
Balance and postural control

• Vestibulo-spinal reflexes
  – generate reactions that compensate for displacements of the head
  – postural responses evoked which stabilize the body to facilitate vertical alignment
  – extensor activity is induced on the side to which the head in inclined, and flexor activity is induced on the opposite side
Balance and postural control

• Vestibulo-colic reflex
  – Neck muscle activation to stabilize the head with respect to space
  – Compensates for displacements of the head that occur during gait (primarily pitch)
Vestibular Loss
Roles in balance / postural control

- Vestibular mechanisms control neck, trunk and hip muscle activation to stabilize the head. Somatosensory cues are more responsible for activation of distal muscles.
- Primarily responsible for generating hip > ankle strategies.
- With somatosensory loss, a hip strategy is adopted in situations where an ankle strategy would have been more efficient.
- The intensity of evoked responses to perturbations is disrupted with vestibular deficiency, timing is less affected.
Gait

Eyes open

Eyes closed
Gait

Head turns (yaw)  Head turns (pitch)
Functional regions of the cerebellum

• Midline (Vermal) regions regulate balance and eye movements and control medial motor systems. Midline cerebellar lesions cause unsteady gait (truncal ataxia) and eye movement abnormalities (nystagmus), which are often accompanied by vertigo, nausea & vomiting.

• More lateral areas of the cerebellum control muscles of the extremities. Lateral cerebellar lesions cause limb ataxia.
Cerebellum

• The cerebellum plays a central role in “recalibrating” ocular motor reflexes with the goal of maximizing visual performance.

• Disease to the cerebellum
  – 1. Directly disrupts the control of eye movement / balance
  – 2. Impairs the adaptation process
Acrophobia