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Assessing Vestibular Dysfunction After Concussion

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Disclosures

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Learning Outcomes

After this course, participants will be able to

- Identify 3 vestibular disorders common after concussion.
- Explain how to perform testing for vestibular dysfunction after concussion using appropriate tools.
- Describe how to determine central vs. peripheral pathology after testing.

Dizziness after Concussion

- Dizziness and imbalance accounts for 40-60% of symptoms
 - Prevalence is 23-81% in the days after injury
- Identified as one of the most common symptoms in high school and collegiate athletes
 - Second only to headache in symptom frequency
- Predictor of prolonged recovery
 - Has a 6 fold increased risk for developing PCS compared to those without dizziness
 - Independent predictor of failure to return to work
 - Persistent dizziness and imbalance were the predominant symptoms after 3 months (Hoffer et al 2015)

Statistics

- 50% of concussed athletes report dizziness
- 40% report balance disturbance
- Positional vertigo (28%), vestibular migraines (41%), and spatial disorientation (19%) are commonly reported

(Ferris et al 2021)

Statistics

- BPPV is the most common cause of dizziness after concussion
 - Prevalence 10-57%
- 30% of patients have combined peripheral and central vestibular dysfunction

Causes of Dizziness after Concussion

- Direct injury to the vestibular system
- Microstructural injury to the CNS
 - Often times peripheral and central injury occur together
- Injuries to visual system and cervical spine can affect vestibular outputs
- Psychological factors
 - Anxiety
 - Depression

Vestibular Injury

- Injury to the peripheral vestibular sensory organs or central vestibular pathways can produce
 - Dizziness / Imbalance
 - Postural instability
 - Visual blurring
- Other mechanisms (Choi et al, 2015)
 - Shearing effect on the root of CN VIII
 - Direct injury to otolith organs, semicircular canals, and vestibule
 - Endolymphatic duct disruption (Meniere's disease)
 - Perilymph fistula

Common Vestibular Issues

- Benign Paroxysmal Positional Vertigo (BPPV)
- Labyrinthine Concussion / Hypofunction
- Visual Motion Sensitivity
- Vestibular Migraine

BPPV

- Most common peripheral vestibular disorder
- Accounts for up to 57% of dizziness
- Higher incidence of atypical canal, multiple canals, bilateral and recurrent
- Study of military patients with concussion found 1/3 with dizziness had evidence of BPPV (Wang et al 2021)
 - Prompt treatment resulted in more rapid return to duty

Labyrinthine Concussion / Hypofunction

- Auditory and/or vestibular dysfunction of the inner ear without temporal bone fracture
- Compression and vibration forces are transmitted through the skull to the inner ear (Choi et al 2013)
 - Pulsation of the inner ear fluids may damage inner ear hair cells and cause lacerations or hemorrhage of the membranous labyrinth
- Macula of the otolith organs may be more vulnerable to pressure waves
 - Both otolithic organs are susceptible to injury

Visual Motion Sensitivity / Spatial Disorientation

- Inability to centrally integrate visual and vestibular information (Kontos et al 2017)
 - Increased awareness of visual stimuli
 - Increased symptoms in busy environments
- Visuovestibular deficits are often persistent symptoms
- Predictors of prolonged recovery

Vestibular Migraine

- Headache is the most common reported symptom after concussion
 - Vestibular migraine is second most common cause of vertigo after BPPV (in general) (Shen et al 2020)
 - Most common cause of spontaneous vertigo
- Vestibular migraine must have dizziness associated with 50% of headaches (Beh 2022)
 - Do not necessarily have associated headache

Vestibular Migraine (Sufrinko et al 2019)

- Concussed athletes with a family history of migraine were at an increased risk for post-traumatic migraine following concussion compared to athletes with no history of migraine
- Athletes with post-traumatic migraine experience worse neurocognitive and vestibulo-oculomotor impairment following concussion

Central Injury

- Direct injury to brainstem or cerebellum
 - Vestibular nuclei
 - Central pathways
- Abnormalities in oculomotor function can indicate damage to CNS pathways
 - Cerebral hemispheres
 - Cerebellum
 - Brainstem

(Akin et al 2017)

Concussion & Auditory Symptoms

- 50 - 92% of concussion patients (including non-blast injuries) report auditory issues
- Primary auditory symptoms after concussion
 - Tinnitus
 - Noise sensitivity
 - Auditory processing difficulty
- Hearing loss can occur, but many times these symptoms occur in the absence of hearing loss

Anatomy and Physiology of the Vestibular System



Vestibular Anatomy

- A bony labyrinth that contains auditory and vestibular organs
- A membranous labyrinth that is within the bony labyrinth
- Supplied by CN VIII

Bony Labyrinth

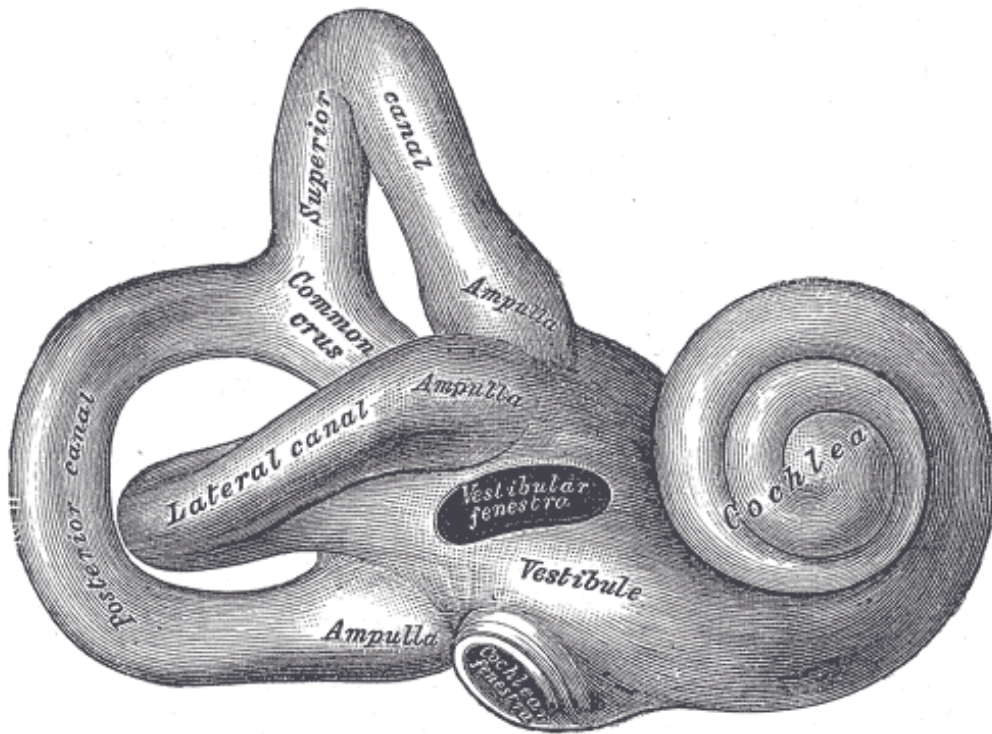


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Membranous Labyrinth

- 3 semicircular canals
 - Anterior, posterior, and horizontal
 - Primarily sense angular acceleration
 - Aligned at right angles to one another with the horizontal canal sloping down 30°
- 2 otolithic organs
 - Sacculle = vertical plane
 - Utricle = horizontal plane
 - Primarily sense linear acceleration and head tilt

Semicircular Canals

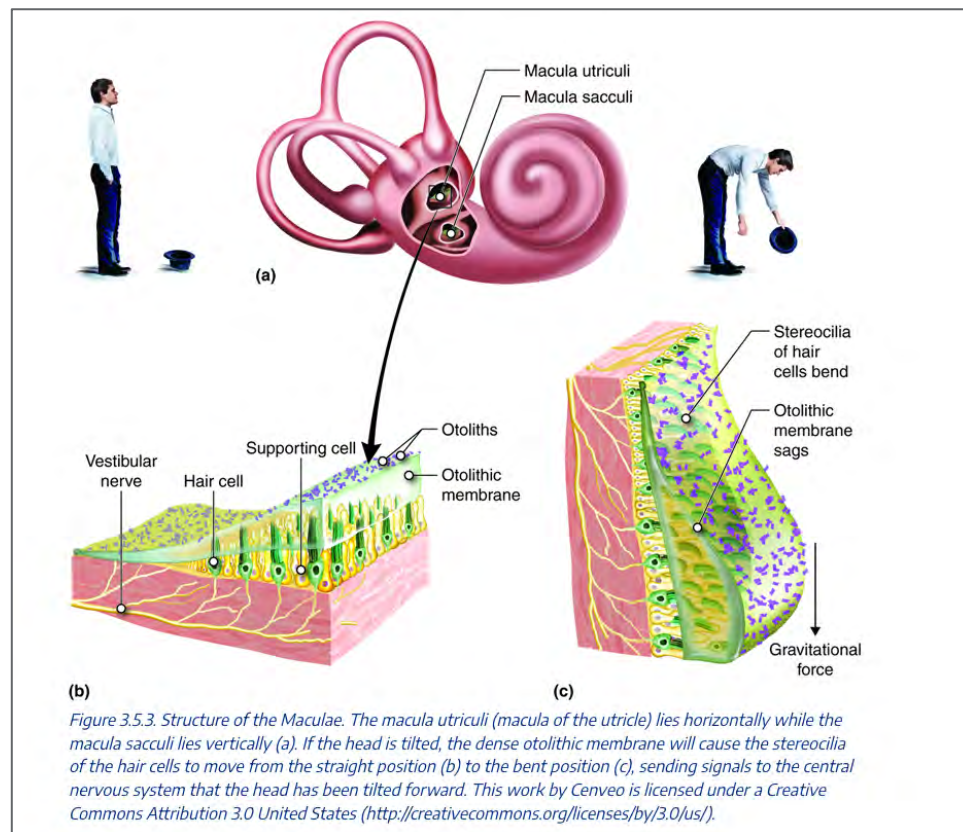
- Provides sensory input about head velocity, enabling the VOR to generate an eye movement equal in velocity to the head (stabilizing the eyes for clear vision)
- Contains endolymph
- Coplanar pairing / sensory redundancy
- Push-pull relationship

Semicircular Canals

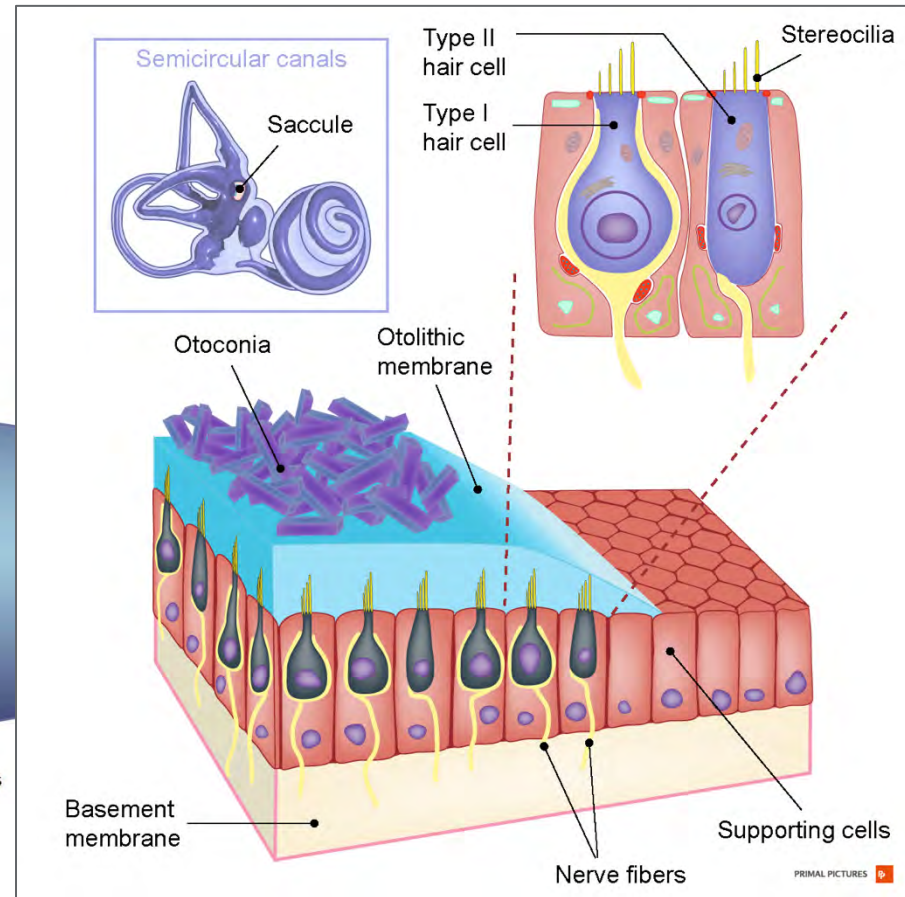
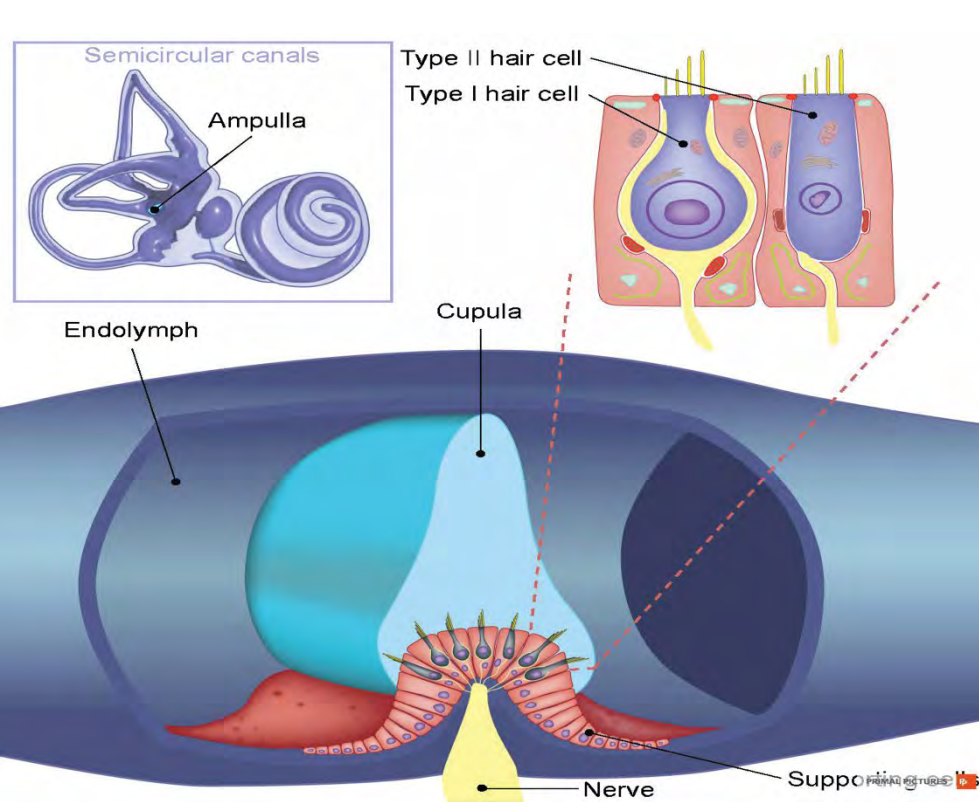
- Perpendicular Relationships
 - R Anterior/L Posterior
 - L Anterior/R Posterior
 - Right Horizontal/Left Horizontal
- Crista is located at the end of each canal
 - Contains the cupula and the ampullary crest

Otolith Organs

- Shear forces from the otoconia
 - Translates: 'ear rocks'
- Linear motion
 - Acceleration
 - Deceleration
- Utricle
 - Horizontal plane
- Saccule
 - Vertical plane
- Contains the macula



Vestibular Anatomy



Vestibular Physiology

- Information from the 3 balance systems is processed in the brainstem and the cerebellum
 - Provides motor and perceptual outputs
 - Motor output is mediated via VOR and VSR

Central Connections

- Primary vestibular afferents originate at the hair cells, enter the brainstem between the pons and medulla, and proceed to the cerebellum or vestibular nuclei
- There are four nuclei and each SCC and otolithic organ has its own neural network

Vestibular Nuclei

- Superior: to eye muscles: VOR
- Lateral: to Spinal Cord: VSR
 - Lateral Vestibulospinal Tract
- Medial: to Spinal Cord and eye: VSR and VOR
 - Medial Vestibulospinal Tract
- Inferior: Reticular Formation

Vestibulo-Ocular Reflex (VOR)

- Vestibular input is used to hold images stable on the retina during head rotations
- The SCC's signal how fast the head is rotating and the oculomotor system responds by rotating the eyes at an equal velocity in the opposite direction

Vestibulo-spinal Reflex (VSR)

- The vestibular system provides the CNS with info about the movement and position of the head with respect to gravity and inertial forces
- Causes excitation of the extensor musculature to help stabilize our body

Reticular Formation

- The reticular formation is not anatomically well defined because it includes neurons located in diverse parts of the brain
 - The neurons of the reticular formation are excited by a variety of sensory stimuli that are conducted from the somatosensory, auditory, visual, and visceral sensory systems
 - Responsible for general arousal / alertness, vital functions, attention, adjusts transmission of pain information, and consciousness levels
- 

Vestibular System

- Function
 - Posture and balance control
 - Vestibulospinal Reflex (VSR)
 - Knowledge of self movement
 - Saccule and utricle
 - Semicircular canals
 - Visual fixation during head movement
 - Vestibular Ocular Reflex (VOR)

Medical Testing



Medical Testing

- Video Nystagmography (VNG)
- Cervical Vestibular Evoked Myogenic Potential (cVEMP)
- Ocular VEMP
- CT scan

VNG

- Battery of tests to identify causes of dizziness
 - Oculomotor Function
 - Smooth Pursuit
 - Saccades
 - Optokinetic nystagmus
 - Positional Testing
 - Dix-Hallpike
 - Calorics

Calorics

- “Gold standard” for identifying peripheral unilateral vestibular hypofunction (UVH)
- Uses a temperature gradient to deflect the cupula of the horizontal canal and generate nystagmus by blowing cold and warm air into the ear
- Normal individuals should have nystagmus during testing
- Abnormal test is a weakness of $\geq 25\%$
- Only examines horizontal function, which is supplied by the superior vestibular nerve, so will not show inferior nerve involvement

VEMP

- Performed to determine pathology in the otolith organs
- cVEMP
 - Performed by placing electrodes over the sternocleidomastoid muscle, which must be contracted during the test
 - Abnormal result would be absence of muscle contraction, which would also indicate side of lesion
 - Tests the inferior vestibular nerve
 - Fair to good test – retest reliability

VEMP

- oVEMP
 - Performed by placing electrodes over the inferior oblique eye muscle, and patients must be looking up to bring the muscle closer to the electrodes
 - Abnormal result would be absence of muscle contraction on the contralateral side
 - Tests the superior vestibular nerve
 - Excellent test – retest reliability

VEMP

- VEMP has become a useful tool for also diagnosing superior canal dehiscence and Meniere's disease
- VEMPs are often absent in the healthy elderly

(Arshad et al 2017)

CT scan

- X-ray technique to determine fractures or thinning bone
 - Used to detect temporal bone fractures
 - Vestibular system located behind the temporal bone
 - Used to detect thinning of the bony labyrinth of the superior canal
 - Superior canal dehiscence

Clinical Testing



Tinnitus Handicap Inventory

- Most widespread (and validated) questionnaire for measuring severity of tinnitus
- Score ranges from 0 – 100 with higher score resulting in more perceived handicap
- Minimal clinically significant change is 7 points
- Highly relevant improvement is 17 points
- Easy to perform

Head Impulse Test

- Unpredictable, **small-amplitude**, rapid head thrust
- Patients with vestibular deficits will have to make corrective saccade to refix on the target
- Affected side is positive test in direction of the head thrust
- Caused by a low gain of the vestibular system
- Head thrust test has been shown to be a reliable (and the best) bedside test to determine hypofunction

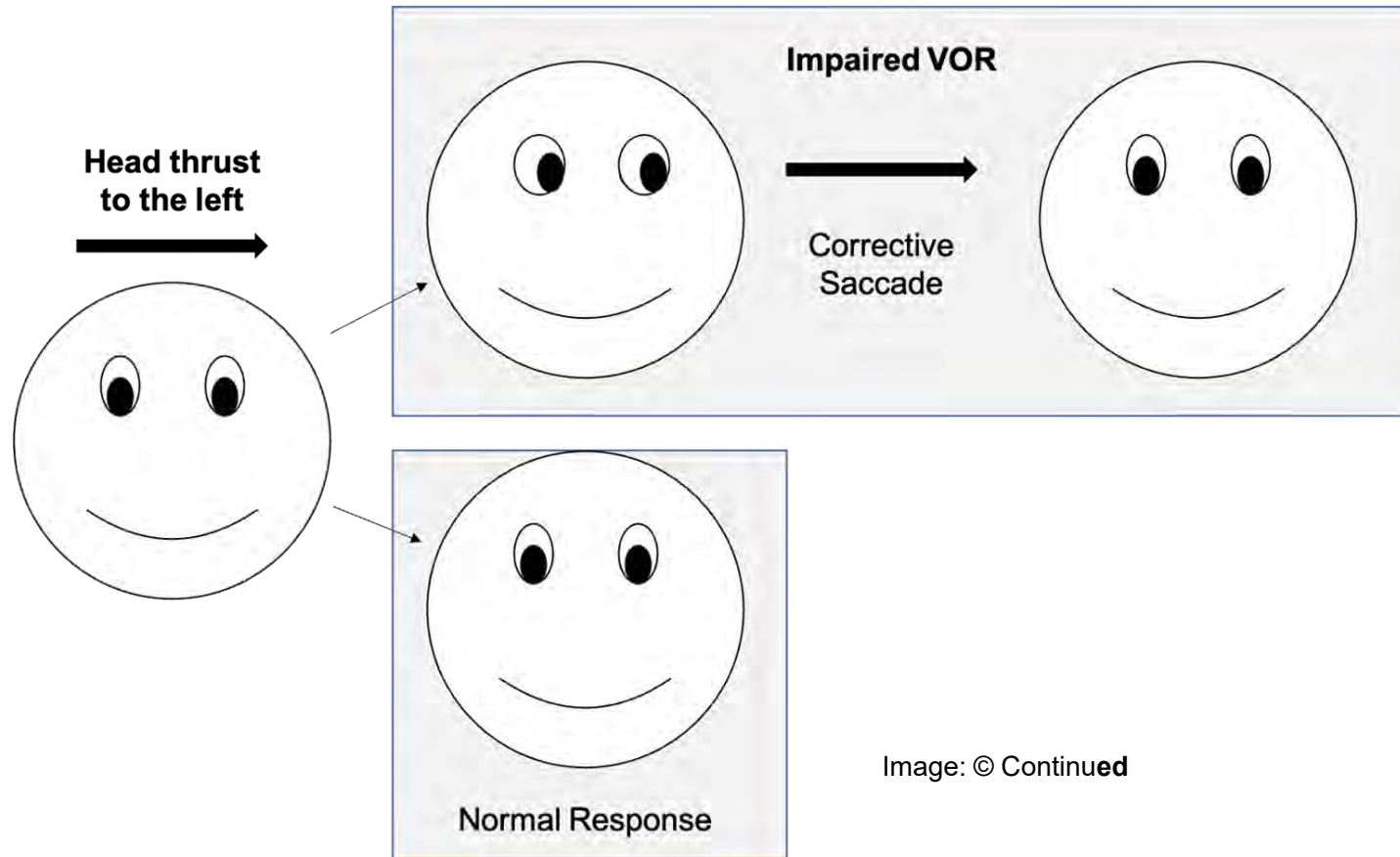


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Signs & Symptoms of BPPV

- Dizziness with positional changes
 - rolling over in bed
 - looking up
 - bending over
- Nausea due to excessive dizziness
- Loss of balance with gait
- Sense of “floating” or “swimming”

Dix-Hallpike

- Patient MUST keep eyes open and stay in provoking position
- Important to explain procedure thoroughly and the expected results
- This test is considered the gold standard for the diagnosis of posterior canal BPPV
- Should test both sides



Image: Creative Commons, Jeremy Hornibrook "Benign Paroxysmal Positional Vertigo (BPPV): History, Pathophysiology, Office Treatment and Future Directions", *International Journal of Otolaryngology*, vol. 2011, Article ID 835671, 13 pages, 2011.

Dix-Hallpike

- Patient begins in long sitting
- Turn patient head 45 degrees to side being tested
- Support patient shoulder with your forearm
- Have patient lie down as quickly as possible
- Extend neck 30 degrees
- Have patient focus on target (tip of nose) to keep eyes still, unless using vision blocking lenses
- Need to maintain position for 45 seconds (can take up to 25 seconds for otoconia to traverse $\frac{1}{4}$ of the canal)

Sidelying Test

- Alternative (and valid) test to Dix-Hallpike
- Adaptable to patients with limited range of motion and those who have difficulty relaxing
- Results are comparable to Dix-Hallpike

Sidelying Test

- Patient begins sitting at edge of mat
- Patient head is turned 45 degrees *AWAY* from side being tested
- Patient lies down to side being tested
- Position is held for one minute

Results

- Posterior Canal
 - Upbeating, torsional nystagmus to affected side
- Anterior Canal
 - Downbeating, torsional nystagmus to affected side OR downbeating
- Horizontal Canal
 - Horizontal nystagmus
 - If seen, should confirm with a roll test
- Canalithiasis – symptoms last < 60 seconds
- Cupulolithiasis – symptoms last > 60 seconds

Roll Test

- Patient MUST keep eyes open and stay in provoking position
- Patient will experience vertigo and nystagmus in both directions due to debris moving back and forth within the canal

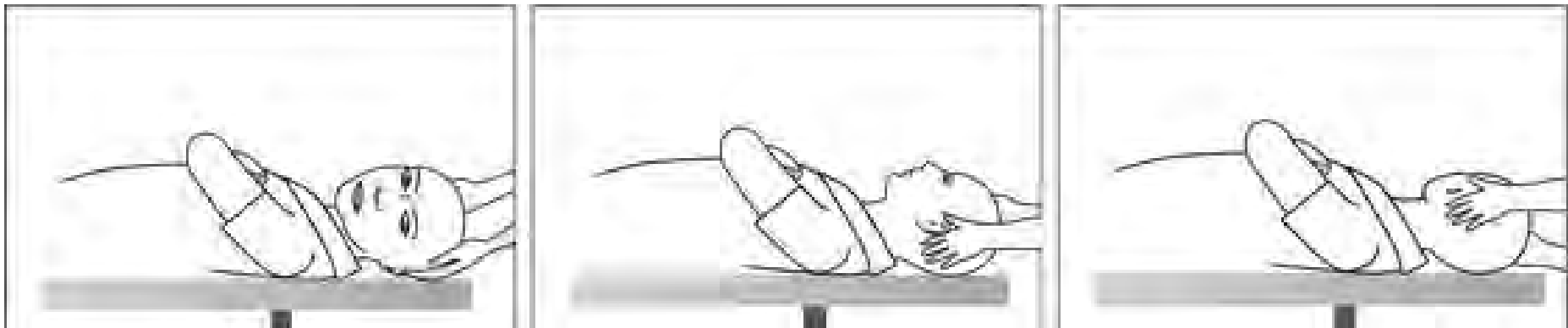


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Roll Test

- Patient lies supine with neck flexed 30 degrees to position horizontal canal perpendicular to horizontal plane
- Turn head 90 degrees to affected side as quickly as possible
- Have patient focus on target (tip of nose) to keep eyes still
- Repeat to other side
- If patient is unable to turn head 90 degrees, have them turn body to achieve 90 degrees

Testing Results

- Canalithiasis
 - Geotropic nystagmus (beating towards the ground)
- Cupulolithiasis
 - Apogeotropic nystagmus (beating away from the ground)

Recovery

- BPPV should resolve quickly
- Recovery can take months
 - Pediatric patients recovery took an average of 40 days with vestibulo-ocular dysfunction compared to 21 days for those without (Ellis et al 2015 & 2017)
 - Patients with fixed peripheral vestibular deficits should be improved by 3 months (Gianoli 2022)

Summary

- Dizziness is the second most common symptom after headache with concussion
- Dizziness is a predictor of prolonged recovery
- Vestibular rehabilitation has been shown to reduce recovery times and improve overall function
- Shorter time to intervention improves outcomes faster

Questions?



References

- Akin FW, Murnane OD, Hall CD, and Riska KM. Vestibular consequences of mild traumatic brain injury and blast exposure: a review. *Brain Injury* 2017. 31(9): 1188-1194.
- Arshad Q, Roberts RE, Ahmad H, Lobo R, et al. Patients with chronic dizziness following traumatic head injury typically have multiple diagnoses involving combined peripheral and central vestibular dysfunction. *Clin Neurol Neurosurg* 2017. 155: 17-19.
- Bhattacharyya N, Gubbels SP, Schwartz SR, et al. Clinical practice guideline: benign paroxysmal positional vertigo (update). *Otolaryngol Head Neck Surg.* 2017;156(3S):S1 - 47.
- Choi MS, Shin SE, Yeon JY, Choi YS et al. Clinical Characteristics of Labyrinthine Concussion. *Korean J Audiol* 2013. 17: 13-17.
- Ellis MJ, Cordingley D, Vis S, Reimer K, Leiter j, and Russell K. Vestibulo-ocular dysfunction in pediatric sports-related concussion. *J Neurosurg Pediatr* 2015. 16: 248-255.

References

- Gianoli G. Post-concussive Dizziness: A Review and Clinical Approach to the Patient. *Front Neurol* 2022. 12: 1-8.
- Herdman, Susan J: *Vestibular Rehabilitation: Fourth Edition*. F.A. Davis Company, Philadelphia, 2014.
- Marcus HJ, Paine H, Sargeant M, et al. Vestibular dysfunction in acute traumatic brain injury. *Journal of Neurology* 2019. 266: 2430-2433.
- Skora W, Stanczyk R, Pajor A, and Jozefowicz-Korczynska M. Vestibular system dysfunction in patients after mild traumatic brain injury. *Annals of Agricultural and Environmental Medicine* 2018. 25(4): 665-668.
- Theodoroff SM, Papesh M, Duffield T, et al. Concussion Management Guidelines Neglect Auditory Symptoms. *Clin J Sport Med* 2020. 1-4.
- Wang A, Zhou G, Kawai K, et al. Benign Paroxysmal Positional Vertigo in Children and Adolescents With Concussion. *Sports Health* 2021. 13(4): 380-386.

References

- Zemen F, Koller M, Figueiredo R, et al. Tinnitus Handicap Inventory for Evaluating Treatment Effects: Which Changes are Clinically Relevant? Otolaryngology – Head and Neck Surgery 2011. 145(2): 282-287.