

Vestibular Concerns Following Sport-Related Concussion

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Outline

1. Vestibular system structure and function
2. Associated conditions
3. Dizziness, balance impairments, vestibular pathology, cranial nerve palsy
4. Physical examination of vestibular system
5. Treatment and rehabilitation concerns

Peripheral Sensory Apparatus

- Bony Labyrinth
 - Semi-circular canals
 - Cochlea
 - Vestibule
- Membranous labyrinth
 - Membranous portion of SCC
 - Otolith organs
 - Utricle
 - Sacculle

Vestibular Function

- Detection of angular and linear acceleration
- Relation of head with respect to gravity
- Functional outcomes
 - Oculomotor: gaze stabilization
 - Vestibulospinal: contribution to postural control

Vestibular Reflexes

- Vestibulo-ocular reflex (VOR)
 - Generates eye movements that enable clear vision when the head is moving
- Vestibulocollic reflex (VCR)
 - Acts on neck musculature to stabilize the head
- Vestibulospinal reflex (VSR)
 - Generates compensatory body movements to maintain head and postural stability (i.e. prevent falls)

Why Be Concerned With Vestibular Function?

- Dizziness
- Balance Impairments
 - Sensory disorganization
- Vestibular Pathology
- Cranial nerves
 - Vestibulocochlear

Dizziness and Balance Impairments

- May affect up to 20-50% of mild-moderate TBI patients (Zollman, 2011)
- Second most commonly reported symptom in 61-72% of athletes (Guskiewicz, 2000, 2001; Lovell, 2006)

- One of the five most common complaints that distinguish post-concussive patients from healthy controls (Chamelin, 2004)
- Predictor of protracted recovery (Lau, 2009)

Head Trauma Induced Dizziness

Dizziness

- Nonspecific term that can refer to
 - Presyncopal lightheadedness
 - Vertigo
 - Sense of imbalance
 - Mutisensory dizziness
- Broad categories
 - Vestibular
 - Non-vestibular

Dizziness Classification

- Vestibular
 - Ischemia
 - Hemorrhage
 - Direct trauma
 - Benign positional vertigo (BPV)
 - Labyrinthine concussion
 - Decreased processing speed
 - Migraine headache
 - Concomitant injuries to visual or musculoskeletal system can affect vestibular output
- Non-vestibular
 - Positional orthostasis
 - C-spine injury
 - Medications (anithypertensives, anticonvulsants)
 - Hyponatremia
 - Vestibular epilepsy

Pathophysiology of Dizziness and Balance Disorders

- Complex system
- Multiple sensory inputs
- Visual, vestibular, somatosensory
- Injury to any component can result in dizziness and imbalance
- Head injury that does not result in TBI may result in dizziness

Clinical Presentation: Dizziness and Balance Impairments

- Lightheadedness
- Spinning or rotating sensation
- Balance problems

Examination: Dizziness and Balance Impairments

- Objective measures
 - Dynamic Gait Index
 - Measures of gait velocity
 - Dix-Halpike Test (BPPV)
 - Balance assessment
- Self-report measures

- Dizziness Handicap Inventory
- Vertigo Handicap Questionnaire
- Vertigo Symptom Scale

Vestibular Pathology

- 30-65% of TBI patients will present with some variety of vestibular pathology (Herdman, 2007)
- TBI confounds vestibular pathology
- Assess and treat patients differently from those with only peripheral vestibular deficits
- Mechanism of injury
- Incidence of other neurologic deficits and persistent symptoms complicate recovery

Labyrinthine Concussion

- Inner ear concussion
 - Most common vestibular sequela of TBI
- Symptoms
 - High frequency sensorineural hearing loss
 - BPPN/V
 - Postural imbalances
 - Gait ataxia

BPPV

- Results from intense acceleration of the utriclular otolithic membrane which results in displacement of otoconia to the posterior SCC
- Displaced otoconia may result in displacement of the cupula in response to gravity in specific positions.
- BPPV produces a transient positional nystagmus
- Transient vertigo

Clinical Presentation: Vestibular Pathology

- Dizziness
- Vertigo
- Nausea
- Disequilibrium
- Visual disturbances

Examination: Vestibular Pathology

- Dix-Hallpike Test
- Observation of visual tracking
 - Nystagmus
 - Saccades
 - Pursuits
- Dynamic Gait Index
- Clinical Test of Sensory Interaction on Balance

Cranial Nerve Palsy: Etiology

- Acceleration-Decceleration
- Shearing
- Skull fracture
- Intracranial hemorrhage
- Vascular occlusion

Cranial Nerve Palsy

- Most frequently injured
 - CN I: Olfactory
 - CN VII: Facial
- **CN VIII: Vestibulocochlear**
 - Less commonly injured
 - CN II: Optic
- **CN III: Oculomotor**
 - Rarely injured
 - CN V: Trigeminal

Assessing Vestibular Function

- Diagnostic
 - Semicircular canals
 - Caloric irrigation
 - Rotary chair
 - Vestibular autorotation test (VAT)
 - Otoliths
 - Vestibular evoked myogenic potential testing (VEMP)
 - Off vertical axis rotation
 - Subjective visual vertical
- Clinical Tests
 - Interview / patient history
 - Oculomotor screening
 - SCC and otoliths
 - Functional tests
 - Gaze stability
 - Balance

Oculomotor Screening

- Smooth pursuit and ocular ROM
- Saccades
- VOR suppression
- Gaze stability
- Eye alignment

Smooth Pursuits

- Follow finger or object in an H or X pattern
- Eye movement should be smooth with no corrective saccades

Saccades

- Look at nose then finger to left, back to nose, finger to right
- Repeat looking up and down
- Movement should be smooth
- No over/undershoot or corrective saccades

VOR Suppression

- Testing that the visual system can override the VOR
- Have patient look at your nose while you move their head
- Should be no movement of eyes off fixation on your nose

Gaze Stability

- Focus on stationary object while moving head side to side or up and down
 - Vertical/Horizontal: any observable nystagmus, dizziness, blurriness, slowed movements
- Convergence

- Near point <6-8cm

Eye Alignment and Symmetry

- Ask patient to look at target 6-8 feet away
- Observe eye alignment
- Should be symmetrical at center
- Left-right
- Up-down

Clinical Tests of SCC Function

- Head thrust or head impulse test
- Head shake
- Dynamic visual acuity (DVA)

Head Impulse Test

- Assessing VOR
- Patient looks at your nose
- Gentle, rapid passive movement of head left and right
- Done by a trained individual
- Positive if corrective saccade is noted

Head Shake Test

- Similar to Head Thrust
- Vision blocked (goggles or eyes closed)
- Patient actively helps rotate head 20 times each side
- Open eyes wide
- Look for presence of nystagmus
- Positive if more than 2 beats

Dynamic Visual Acuity

- Read print moving to smaller lines until patient misses 3/5
- Line above = acuity
- Passively move head left-right 15 degrees to each side
- Difference in the 2 scores is the DVA score
- Positive test is 2 or more lines

King-Devick Test

- Evaluates visual tracking and saccadic eye movements
- Initially used for reading and dyslexia
- Sideline post-concussion showed significant worsening from BL: 46.9 vs. 37.0 s, $P = 0.009$ (Galletta, 2011)

Clinical Tests of Otolith Function

- Subjective Visual Vertical
- Balance

Subjective Visual Vertical

- Bucket test
- Level/goniometer attached to bucket
- Vertical line inside
- Patient's goal is to get the line to vertical
- Examiner slowly moves bucket

- Patient indicates when to stop

Balance Assessment

- Heel to opposite knee
- Finger to nose
- Romberg test
- Computerized posturography (SOT, CTSIB)
- Clinical balance tests (BESS, SEBT)
- Functional balance tests (TUG, Gait)

Sensory Systems

Multisensory Integration

- Process inputs from the periphery as the environment changes
- Weight inputs based upon relevance (Sensory Reweighting)
- Select appropriate sensory input based upon
- Availability
- Accuracy

Isolation of Sensory Input

- Clinical Test of Sensory Interaction for Balance (CTSIB)
- Sensory Organization Test (SOT)

Somatosensory Ratio

Condition 2 / Condition 1

Does sway increase when visual cues are removed?

Low score = poor use of somatosensory references

Vestibular Ratio

Condition 5 / Condition 1

Does sway increase when visual cues are removed and somatosensory cues are inaccurate?

Low score = poor use of vestibular cues

Visual Ratio

Condition 4 / Condition 1

Does sway increase when somatosensory cues are inaccurate?

Low score = poor use of visual references

NeuroCom™

- Sensory Organization Test
- Motor Control Test
 - Ability of motor system to recover following a perturbation
- Adaptation Test
 - Ability to minimize sway when exposed to irregularities and unexpected changes in support surface properties.

Biodex Play It Safe

M-CTSIB

VSR Sport

- Stability Evaluation Test
- Validated against BESS
- 6 BESS stances done on a portable force plate

- Collects sway path and COG displacement

Balance Error Scoring System

Functional Assessment Balance

- Functional reach test (Katz-Laurer, 2008, 2009)
 - Excellent within session reliability in children with TBI
 - Decreased FRT in children with TBI
- Timed Up and Go (Katz-Laurer, 2008, 2009)
 - Good reliability in children with mTBI
 - Slower TUG, smaller step length, increased step time, increased gait variability with mTBI
- Gait analysis (Katz-Laurer, 2009; Parker, 2007, 2008)
 - Increased variability in step time and length, decreased gait speed in mTBI

Special Concerns with Balance Assessment

- Age (Cumberworth, 2007; Forssberg, 1982; Shumway Cook, 1995)
 - Visual and vestibular functions mature through age 16, somatosensory develops earlier
- Fatigue (Wilkins, 2004; Susco, 2004; Fox, 2008)
 - Decreased postural stability after exertion
 - Increase in BESS errors, recovers in 13-20 min
- Learning effects (Valovich, 2003; Valovich McLeod, 2004)
 - Lower BESS scores by 3rd administration

Treatment and Rehabilitation

- Vestibular suppressants (short term basis)
 - Anticholinergics
 - Antihistamines
 - Benzodiazapines
- Balance Rehabilitation Therapy (BRT)
 - Vestibular rehabilitation

Vestibular Rehabilitation Specialists

- Vision impairments
- Headache
- Dizziness
- Sensory organization impairments

Indications for Vestibular Therapy

- Atypical Recovery
 - Not back to baseline on balance assessment by 10 days post-concussion
 - Impaired dynamic visual acuity tests
 - Dizziness
 - Motion provoked dizziness
 - Nausea
 - Blurred vision with head movement
 - Motion sensitivity

Indications for Vestibular Rehabilitation

- Symptoms
 - Vertigo (especially when lying in bed)
 - Dizziness/ imbalance (no improvement over one week or is persistent beyond two weeks)
- Balance impairments

- Strong Romberg (after one week)
- BESS (if greater than baseline after one week or > 10 errors per set, > 30 total after one week)
- Positive Dix Hallpike +/- improvement or resolution with Epley maneuver
- Patients generally like the active nature of participating in their recovery

Rehabilitation Strategies

- Adaptation
 - Ability of the vestibular system to make long-term changes in the neuronal response to input
- Substitution
 - Using other strategies to replace lost function
- Habituation
 - Reduction in symptoms produced through repeated exposure to the movement

X1 Exercises

- Stationary target
- Subject moves head
- Horizontal and vertical
- Maintains visual fixation on target
- Target should remain clear (focused) while head is moving

X1 Errors

- Not keeping the eyes on the target
 - Instead glancing from side to side
- Making the head movement too large
 - Patient is looking out of the corner of the eyes
- Not moving the head in a consistent in this movement
 - Not staying horizontal

Horizontal Eye Head Exercises

Remembered Target Exercise

- Patient fixates on a small target
- Closes eyes, pretending to look at that target
- Patient makes a horizontal head movement, trying to remember where the target is
- Opens eyes to check whether or not they are still looking at the target
- Aims to foster central pre-programming of eye movements

X2 Exercises

- Target and the head move in opposite directions
- Patient focuses on target

X2 Errors

- Similar to X1 errors
- Confusion when trying to move head and target in opposite directions
- Results in VOR cancellation

Concussion Rehabilitation

- Dual task strategies
 - Combined postural control and cognitive tasks
 - Retrain executive attentional networks
 - Secondary cognitive activities improve postural control (Wulf, 2001; Huxhold, 2006; Resch, 2011)

- Alternative assessments of balance
 - Cleveland Clinic iPad app
 - Built-in accelerometer and gyroscope
 - Allow the device to measure position and movement
- Virtual Reality
 - Wearing head mount display does not impair BESS (Mihalik, 2008)
 - Balance deficits induced by visual field motion up to 30 days post-injury (Slobounov, 2006)
 - Long-term residual visual-motor disintegration in athletes with normal neurocognitive scores (Slobounov, 2006)
- Head Shake SOT
 - Measures impairments in patient's ability to use vestibular inputs while actively moving head
 - SOT condition 2 (eyes closed on a firm surface) and condition 5 (eyes closed on a sway-referenced support surface)
 - Patient wears a head movement monitor
 - Performs a continuous rhythmic head movement about a specified yaw, pitch, or roll axis

Take home points

- Evaluation of the vestibular system is a vital component of concussion assessment
- Dizziness and vertigo are key symptoms
- Oculomotor examination important
- Balance assessment
- Ability to isolate sensory systems a plus
- Vestibular rehabilitation should be considered with atypical recovery