Dizziness and Balance Dysfunction in Traumatic Brain Injury
Diane M. Wrisley, PT, PhD, NCS
Associate Professor
Director of Pre-professional Programs
Department of Physical Therapy
Wingate University

Objectives
• At the end of the lecture the participant will be able to:
  • Describe the anatomy and physiology of the vestibular system
  • Describe the differential diagnosis for dizziness and balance dysfunction following TBI
  • Describe the evaluation for dizziness and balance dysfunction following TBI
  • Describe treatment for common disorders following TBI

Incidence of Dizziness in TBI
• 24-80% initial symptoms
• 20-47% at 5 years
  • Minor TBI: 20 - 32%
  • Moderate TBI: 37 - 47%
  • Severe TBI: 26%
• 23% of a brigade combat team returning from Iraq had TBI
  • 88% due to blast injuries
• Dizziness and Balance Disorders among the top 3 complaints of service members following blast injuries
  • Dizziness 59%
  • Balance dysfunction 26%

Prevalence of Vestibular Dysfunction in TBI
• Of 100 patients with dizziness post-TBI
  • 71% Peripheral Vestibular Dysfunction
  • 61% BPPV
  • 8% Central Vestibular Dysfunction
• Of 58 patients with dizziness post-TBI (military)
  • 28% BPPV
  • 41% Migraine-related Dizziness
  • 19% Spatial Disorientation

Association of Dizziness and TBI
• Dizziness may be due to TBI pathology (CNS)
• Dizziness may be due to vestibular pathology due to TBI
• Dizziness may be underlying cause for TBI (falls)
• Dizziness may complicate rehabilitation for sequelae of TBI
• Dizziness may mimic cognitive impairments seen with TBI
• Cognitive impairments due to TBI may complicate vestibular rehabilitation

Vestibular role in Postural Control
• Provides input on head movement and position
• Provides gaze stabilization
• Provides postural adjustments
  • Vestibular spinal reflexes
Differential Diagnosis for Dizziness Associated with TBI
• Benign Paroxysmal Positional Vertigo
• Labyrinthine Concussion
• Brainstem Concussion
• Central Vestibular Dysfunction
• Cervicogenic Dizziness
• Post-traumatic Meniere’s Disease
• Post-traumatic Migraine-related Vestibulopathy
• Perilymphatic Fistula
• Anxiety-related Dizziness
• Non-vestibular causes

Benign Paroxysmal Positional Vertigo
• Most common form of dizziness
• Presentation
  • Short duration episodic vertigo during head movements
  • May also complain of imbalance, disorientation
  • Worse in am
• Pathophysiology
  • Otoconia become dislodged from utricle and either float in endolymph of semicircular canal or attach to cupula
  • This causes the semicircular canals to respond to gravity
  • Patients demonstrate characteristic nystagmus in response to head movements that has a latency of 2-15 seconds and a duration of <1 minute

Post-traumatic BPPV
• Onset with mild TBI within a few days Katsarkas, 1999
• Higher incidence of bilateral involvement Katsarkas, 1999
• Consider checking all 3 canals on both sides before treating
• Recurrence rate of 26-30% Nunes et al 2000; Epley 1992
• Results in quicker relapses than non-traumatic Gordon et al 2004
• Requires repeated repositioning compared to those with non-traumatic BPPV Gordon et al 2004; Del Rio et al 2004

Labyrinthine Concussion
• Damage to the labyrinth, with or without bony fracture
  • Membranous labyrinth very fragile and easily damaged
• Laboratory findings
  • Unilateral peripheral loss with caloric testing
  • Asymmetric sensorineural hearing loss due to damage to the cochlea
  • Rotational chair testing abnormal if compensation is not complete

Brainstem Concussion
• Shearing on the root entry zone of the 8th cranial nerve may lead to hemorrhage or cell death in the area of the vestibular nuclei
• Signs and Symptoms
  • Dizziness/vertigo
  • Postural instability
  • May be associated with other cranial nerve damage or CNS signs
  • VOR and saccadic eye movement abnormalities
  • Implicated if compensation does not occur with labyrinthine concussion

Central Vestibular Dysfunction
• Dysfunction of the vestibular nuclei, cerebellum and other vestibular pathways
• Presentation
  • Depends on where lesion occurs
    • Less likely to have true vertigo
    • More likely to have constant symptoms
    • More likely to have balance dysfunction
    • More likely to have central nervous system signs
Cervicogenic Dizziness
• A specific form of central vestibular dysfunction
• Responsible for < 1% of all cases of vestibular dizziness
• Diagnostic Criteria
  • History of neck trauma or pathology
  • Symptoms of dizziness and imbalance temporally related to neck pain or headache
  • All other causes of dizziness eliminated
• Current theory of Pathophysiology
  • Aberrant afferent information from C1-C3 causes altered perception of orientation in space

Meniere’s Disease
• Presentation
  • Episodic, usually unilateral (lasts hours to days)
  • Vertigo
  • Hearing Loss
  • Tinnitus
  • Nausea
  • Aural fullness
• Current theory of pathophysiology
  • Swelling, or distension, of the endolymphatic compartment of the inner ear leading to rupture of membranous labyrinth resulting in transient potassium palsy of the vestibular nerve fibers

Migraine-related Vestibulopathy
• A specific form of central vestibular dysfunction
• Current theory of pathophysiology
  • Increased activity in the brainstem
  • Abnormalities in neurotransmitter levels
• Presentation
  • Dizziness may occur before, during, or after a migraine
  • Episodic vertigo, nausea, disorientation, space and motion intolerance associated with headache
  • Symptoms are often exacerbated by specific visual environments
  • Some patients can have migraine without headache, migraine equivalents, with dizziness instead of headaches

Migraine-related Vestibulopathy
• Diagnostic Criteria
  • Absence of documented vestibular pathology
  • Migraine diagnosis according to the International Headache Society (IHS) Criteria
  • Intermittent vertigo or disequilibrium – at least 2 episodes
  • Accompanied by photo or phonophobia or visual aura, not necessarily headache

Post-traumatic Migraine-Related Vestibulopathy
• Patients with post-traumatic migraine had significantly impaired neurocognitive function compared to non-migrainous headache or no headache
  Mnahla et al 2005
  • Caution should be exercised when returning to work or play

Perilymphatic Fistula
• Abnormal communication of the inner-ear and middle-ear spaces via labyrinthine windows or a microfissure of the bony labyrinth
  • Episodic vertigo
  • Sensorineural hearing loss/tinnitus – may be fluctuating
  • Precipitated by increased intrathoracic or intracranial pressure
  • Diagnosis difficult
  • Nystagmus or dizziness with Valsalva maneuver
  • Surgical exploration
Anxiety-related Dizziness

- 41% mild TBI report anxiety 5 years post injury
- Diagnostic Criteria
  - Dizziness is a defining or associated symptom of a psychiatric disorder
  - Dizziness is not correlated with vestibular pathology
  - Vestibular abnormalities common in panic disorder and are associated with space and motion discomfort
  - Common pathways between anxiety, space and motion discomfort, and perception of dizziness/vertigo

Non-Vestibular Causes

- Orthostatic Hypotension
- Medications
- Physical deconditioning
- Musculoskeletal injuries

Evaluation of the Patient with TBI and Dizziness

Subjective Assessment of Dizziness

- Dizziness Handicap Inventory (Whitney and Newman, 1990)
  - 25 item test that assess the self perceived handicap due to dizziness
  - 3 subcategories: functional, emotional, and physical
  - Scored: No: 0; Sometimes: 2; Yes: 4
  - Maximum: 100
  - High test-retest reliability
  - Useful in directing patient interview
  - Questions 1, 5, 11, 13, and 25 are predictive of BPPV
  - Correlates with Physical Function Measures

  - Developed to assess self-perceived disability in patients with vestibular impairments
  - Items include 27 activities of daily living
  - Scale rated from 1 (independent) to 10 (ceasing to participate in the activity)
  - Scored as a median so patients can skip an item and the test still has validity
  - Internal consistency high (Cronbach’s α > .90)
  - Excellent test-retest reliability (r > .87)
Evaluation of the Patient with TBI and Dizziness

- **Thorough History**
  - Relevant medical history
  - Acute or chronic medical problems
  - Family history
  - Description of symptoms: dizziness, vertigo, headache, falls
    - Include frequency and duration
  - Medications
  - Social history
  - Environmental Assessment
  - Cognition

- **Physical Examination**
  - **Cardiovascular Status**
    - Heart rate and rhythm
    - Postural pulse and blood pressure – supine, sitting, and standing
    - Pulse oximetry
  - **Musculoskeletal System**
    - Joint range of motion
    - Muscle strength

Examination of the Patient with TBI and Dizziness

- **Neurological Function**
  - Sensation
  - Reflexes
  - Cranial Nerves
    - Ocular motor function
    - Vestibular function
  - Visual acuity, visual contrast sensitivity, convergence
  - Gait, balance, and mobility levels

Ocular Motor Function

- **Ocular Motor Function**
  - Purpose: To determine if CNS problem and to ensure that eye movements are normal so VOR can be tested
  - Smooth pursuit
    - Smooth eye movement tracking a slowly moving discrete target
    - Mediated by brainstem eye fields, medial longitudinal fasciculus, and cranial nerves III, IV, and VI
    - Abnormalities are seen with cerebellar or brain stem lesions
  - Saccades
    - A quick eye movement or refixation
    - Mediated by frontal eye fields (voluntary saccades), brainstem reticular formation (voluntary and involuntary saccades) and cranial nerves III, IV, and VI
    - Abnormalities are seen with cortical, brainstem and cerebellar lesions

Saccadic Disorder

- Abnormal smooth pursuit and saccades
  - [http://library.med.utah.edu/neurologicexam/movies/cranialnerve_ab_11_x2.mov](http://library.med.utah.edu/neurologicexam/movies/cranialnerve_ab_11_x2.mov)

Dizziness and Balance Dysfunction in TBI
Diane Wrisley, PT, PhD, NCS 10/17/2014
Convergence Insufficiency

• Convergence Insufficiency observed in 23–46% of people with TBI. Alvarez et al. 2012

Convergence Spasm

Clinical Measures of Vestibular Function

• Eye Head Coordination Testing
  • Active and Passive VOR
    • Mediated by labyrinth, VII cranial nerve, and vestibular nucleus
    • Active VOR
      • While the patient looks at a target have them move their head horizontally and then vertically at about 2 cycles/second. Look for refixation saccades, note reports of dizziness or nausea
    • Passive VOR
      • Hold the patient’s head tipped down approximately 30 degrees, move the patient’s head horizontally and vertically at about 2 cycles/second while asking them to focus on your face. Look for refixation saccades, note reports of dizziness or nausea
  • Abnormalities are indicative of vestibular dysfunction

• Head Thrust (Head Impulse Test) Schubert et al. 2004; Halmagyi and Curthoys 1988
  • 95% specificity, 35% sensitivity for detecting vestibular lesion
  • 82% specificity, 71% sensitivity UVL, 84% sensitivity BVL Schubert et al. 2004
  • The patient is asked to fixate on a target while the examiner moves the patients head rapidly to each side
  • The examiner looks for any movement of the pupil during the head thrust and a refixation saccade
    http://library.med.utah.edu/neurologicexam/movies/cranialnerve_n_13_x2.mov

Dix-Hallpike Maneuver

The Dix-Hallpike maneuver-45 degrees rotation and 30 degrees extension over the edge of the bed.

Auditory Testing

- Audiogram and Word Recognition Test (hearing test)
- Tympanometry and Acoustic Reflex Testing
- Brainstem Auditory Evoked Potential Testing
- Electrocochleography

Objective Tests of Vestibular Function

- Electronystagmography/ Videonystagmography
  - Ocular Motor Testing
  - Caloric Testing
  - Positional Testing
  - Earth Vertical Axis Rotation (EVAR or rotational chair testing)
  - Computerized Dynamic Posturography

Vestibular Function Testing

Electronystagmography/Videonystagmography

- Ocular motor testing
- Positional testing

- Caloric testing
  - Warm or cool air or water is placed in the external auditory canal
  - Slow phase velocity of nystagmus is measured and compared between sides
  - % asymmetry
  - Directional preponderance

Vestibular Function Tests

- Earth Vertical Axis Rotation (Rotational Chair Testing)
  - Optokinetic Nystagmus
  - Sinusoidal Stimulation
  - Gain
  - Phase
  - Directional Preponderance
  - Step Stimulation
  - Time constant

- Otolith Testing
  - Off Vertical Axis Rotation
  - Vestibular Evoked Myogenic Potentials (VEMP)
  - Linear sled
Vestibular Function Testing

- Computerized Dynamic Posturography
  - Sensory Organization Test
    - Somatosensory and Visual cues are manipulated to determine how a person uses sensory information for balance
  - Motor Control Test
    - Assesses the motor response to platform translations at various velocities
  - Adaptation Test
    - Assesses how a person adapts to repetitive rotational platform translations

Sensory Organization Test (SOT)

[Diagram of Sensory Organization Test]

Evaluation of Gait and Balance

- Single Item Tests
  - Romberg
    - Developed to test posterior column disease
    - Sharpened Romberg (tandem): holding for < 10 seconds indicate increased risk of falling
  - Single Limb Stance (SLS)
    - Increase risk of injury due to a fall 2 times if cannot perform SLS for 5 seconds

30 Second Chair Stand Test

- Administered using a folding chair without arms, placed against a wall
- Measure number of times a person can come to complete standing in 30 seconds without using arms
- Excellent test-retest reliability r=0.89
- Criterion fitness standards to maintain physical independence

<table>
<thead>
<tr>
<th>Age</th>
<th>60-64</th>
<th>65-69</th>
<th>70-74</th>
<th>75-79</th>
<th>80-84</th>
<th>85-89</th>
<th>90-94</th>
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<tr>
<td>Women</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>13</td>
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<td>Men</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>13</td>
<td>11</td>
<td>9</td>
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</tbody>
</table>

Clinical Test of Sensory Interaction and Balance

- Clinical Test of Sensory Interaction and Balance
  - Shumway-Cook and Horak 2000
  - Reliable
    - Adults with balance dysfunction Kappa ranged from 0.31 to 0.81 Loughran et al 2005
  - Valid
    - Correlates with Sensory Organization Test in people with vestibular dysfunction
    - Inability to maintain stance on foam predicted future multiple falls (OR 4.21)
Clinical Test of Sensory Interaction on Balance

<table>
<thead>
<tr>
<th>Condition</th>
<th>Surface</th>
<th>Vision</th>
<th>Sensory Input</th>
<th>Available</th>
<th>Abnormal Scores Indicate</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Firm</td>
<td>Eyes Open</td>
<td>Accurate Vision</td>
<td>Accurate Somatosensory</td>
<td>Possible motor impairment</td>
</tr>
<tr>
<td>2</td>
<td>Firm</td>
<td>Eyes Closed</td>
<td>Absent Vision</td>
<td>Accurate Somatosensory</td>
<td>Impaired use of somatosensory info</td>
</tr>
<tr>
<td>3</td>
<td>Firm</td>
<td>Visual Conflict Dome</td>
<td>Inaccurate Vision</td>
<td>Inaccurate Somatosensory</td>
<td>Impaired use of somatosensory info</td>
</tr>
<tr>
<td>4</td>
<td>Compliant</td>
<td>Eyes Open</td>
<td>Accurate Vision</td>
<td>Inaccurate Somatosensory</td>
<td>Impaired use of visual info</td>
</tr>
<tr>
<td>5</td>
<td>Compliant</td>
<td>Eyes Closed</td>
<td>Absent Vision</td>
<td>Inaccurate Somatosensory</td>
<td>Impaired use of vestibular info</td>
</tr>
<tr>
<td>6</td>
<td>Compliant</td>
<td>Visual Conflict Dome</td>
<td>Inaccurate Vision</td>
<td>Inaccurate Somatosensory</td>
<td>Impaired use of vestibular info</td>
</tr>
</tbody>
</table>

Evaluation of Gait and Balance

- **Multiple item balance tests**
  - **Berg Balance Scale (BBS)**  
    - 14 items graded on an ordinal scale 0-4
    - Reliable: ICC \( r = 0.91 \) in older adults
    - Scores below 45 indicate increased risk of falling in community dwelling older adults \( \text{Shumway-Cook et al. 1997} \)
    - Scores of < 36 indicate a 100% chance of falling in the next 6 months

- **Tinetti Performance Oriented Mobility Scale (POMA)** \( \text{Tinetti et al. 1986} \)
  - Balance (10 items, 16 points) and Gait (12 points)
  - Subscales
  - Excellent Test-retest reliability in older adults ICC \( r=0.96 \) \( \text{van Iersel et al. 2007} \)
  - Fall risk interpretation
    - 24-28 Low risk of falls
    - 19-23 Moderate risk of falls
    - <18 High risk of falls

- **Gait Tests**
  - **Timed “Up & Go” (TUG)** \( \text{Podsiadlo and Richardson 1991} \)
    - A person is timed while they stand from a sitting position, walks 3 meters (at self-selected speed), turns, walks back to the chair and sits down
    - Reliable: ICC \( r = 0.99 \) in community dwelling older adults
    - Scores of > 11 seconds correctly classify older adults who will fall \( \text{Podsiadlo and Richardson 1991, Trueblood et al. 2001, Wrisley and Kumar 2010} \)

Functional Reach/Multidirectional Reach

**Multidirectional Reach Test Reference Values** (mean age 74 years)

<table>
<thead>
<tr>
<th>Direction</th>
<th>Above average (inches)</th>
<th>Below average (inches)</th>
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<tbody>
<tr>
<td>Forward</td>
<td>&gt;12.2</td>
<td>&lt;5.6</td>
</tr>
<tr>
<td>Backward</td>
<td>&gt;7.6</td>
<td>&lt;1.6</td>
</tr>
<tr>
<td>Right lateral</td>
<td>&gt;9.4</td>
<td>&lt;3.8</td>
</tr>
<tr>
<td>Left lateral</td>
<td>&gt;9.4</td>
<td>&lt;3.8</td>
</tr>
</tbody>
</table>
Evaluation of Gait and Balance

• Dynamic Gait Index (Shumway-Cook and Woollacott 2012)
  • 8 gait tasks graded on an ordinal scale (0-3)
  • Reliable: ICC r=0.82 community-dwelling older adults
  • Scores of ≤19/24 correctly identify older adults at risk for falling
  (Shumway-Cook et al 1997)

• Functional Gait Assessment (Wrisley et al 2004)
  • 10 item test graded on an ordinal scale (0-3)
  • Reliability: ICC r= 0.93 in healthy adults
  • Scores of ≤ 22/30 correctly classify older adults who will fall
  (Wrisley and Kumar 2010)
  • LR+: 3.6
  • LR-: 0.00

Evaluation of Gait and Balance

• Timed Gait
  • Low gait velocity (<0.7 m/sec) increases risk of falls
  (Montero-Odasso et al 2005; Verghese et al 2009)
  • Gait variability (step length, double support phase) increases risk
  of falls

Four Square Step Test (Dite and Temple 2002)

• Measure the amount of time it takes to walk around the squares
  clockwise then counterclockwise
  • Scores of > 12 seconds indicate increased risk of falls in
  people with vestibular dysfunction
  (Wrisley and Temple 2002)
  • Excellent test-retest reliability
  • Concurrent validity established

Table 1.
Functional Gait Assessment Total Scores by Decade

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>N</th>
<th>Minimum Score</th>
<th>Maximum Score</th>
<th>Mean</th>
<th>SD</th>
<th>95% Confidence Interval</th>
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<tbody>
<tr>
<td>46-59</td>
<td>27</td>
<td>21</td>
<td>59</td>
<td>28.9</td>
<td>1.5</td>
<td>28.3-29.5</td>
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<tr>
<td>56-59</td>
<td>55</td>
<td>25</td>
<td>59</td>
<td>28.4</td>
<td>1.6</td>
<td>27.9-29.0</td>
</tr>
<tr>
<td>66-69</td>
<td>63</td>
<td>20</td>
<td>59</td>
<td>27.1</td>
<td>2.5</td>
<td>26.5-27.7</td>
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<tr>
<td>76-79</td>
<td>44</td>
<td>16</td>
<td>59</td>
<td>24.9</td>
<td>3.6</td>
<td>23.9-26.0</td>
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<tr>
<td>80-89</td>
<td>55</td>
<td>10</td>
<td>28</td>
<td>20.8</td>
<td>4.7</td>
<td>19.2-22.6</td>
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<tr>
<td>Total</td>
<td>200</td>
<td>10</td>
<td>59</td>
<td>26.1</td>
<td>4.0</td>
<td>25.5-26.6</td>
</tr>
</tbody>
</table>

Mini-BESTest

• 14 items based on original BESTest
• Scored on ordinal scale of 0-2
• Excellent test-retest reliability
• Excellent correlation with BESTest and Global Rating of Change
• Normative Scores not established
• Scores of < 20/28 indicate increased risk of falling in people with
  Parkinson Disorder
• http://www.bestest.us/files/7413/6380/7277/MiniBEST_revised_fin a_1_3_6_13.pdf

Mini-Balance Evaluation Systems Test (mini-BESTest)

I. Anticipatory Postural Adjustments
  1. Sit to Stand
  2. Rise to Toss
  3. Stand on One Leg

II. Reactive Postural Responses
    4. Compensatory Stepping Correction – Forward
    5. Compensatory Stepping Correction – Backward
    6. Compensatory Stepping Correction – Lateral

III. Sensory Orientation
    7. Stance feet together – eyes open, firm surface
    8. Stance feet together – eyes closed, foam surface
    9. Incline Toe Up – Eyes Closed

IV. Stability in Gait
    10. Change in Speed
    11. Walk with Dual Task – Horizontal
    12. Walk with Pivot Turn
    13. Step over obstacle
    14. Timed “Get Up & Go” with Dual Task
Differential Diagnosis

- Need to determine
  - Is the dizziness vestibular in origin?
  - If it is vestibular is it peripheral, central or both?
  - Is it a loss of function, irritative or mechanical?

Unilateral Peripheral Vestibular Dysfunction

Bilateral Peripheral Vestibular Dysfunction

Central Vestibular Dysfunction

BPPV

Onset
- Sudden
- Sudden or gradual
- Gradual
- Sudden

Frequency
- Episodic
- Constant
- Constant
- Episodic

Duration
- Minutes to hours
- Hours to days
- Hours to Days
- Seconds to minutes

Symptoms
- Vertigo, nausea, imbalance
- Dizziness, imbalance
- Lightheadedness, imbalance
- Vertigo

Acute Management Issues

- Musculoskeletal involvement may limit types of exercise a patient can perform
- Vestibular rehabilitation exercises may need to be modified or postponed
- Due to high prevalence, BPPV should be ruled out on all patients
- Cognitive impairments
  - Memory problems may influence follow through of exercises
    - Family involvement
    - Use of a compliance worksheet
  - Confusion and decreased processing may increase space and motion discomfort

Chronic Management Issues

- Vestibular function testing if dizziness persists or vestibular pathology suspected
- Increase activity level incrementally as long as symptoms are under control
- Migraine management/prevention
- Sleep disorder management if not resolving
- Stress management may be indicated

Treatment Considerations

- BPPV
  - Canalith repositioning maneuver
Treatment Considerations

• Post-traumatic Meniere’s Disease
  • Control Fluctuations
  • Vestibular Rehabilitation may decrease frequency and intensity of attacks Dowdal-Osborn 2002; Hahn et al 2001

• Post-traumatic Migraine-related Vestibulopathy
  • Migraine management
  • Control symptoms of space and motion discomfort
  • May need additional emotional support Wrisley et al 2004

Questions?