Diagnosis and Treatment of Vestibular Disorders in mTBI

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Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Poll Question:

What type of vestibular damage do you think may be more common in mTBI with blast exposure?

1) Unilateral Canal
2) Unilateral Otolith
3) Bilateral Canal
4) Bilateral Otolith
5) None
What does vestibular dysfunction look like?
Acute Vestibular Disorder
Chronic Vestibular Disorder
Research Approach

- Assess balance system a number of ways
  - Posturography – sway while standing with eyes open and closed
  - Vestibular Ocular Reflex – focused on otolith function by examining ocular torsion during roll tilt as well as unilateral centrifugation
Postural Sway in Veterans

Condition 1  Condition 5

Equilibrium Score

Vestibular Score

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Assessing Ocular Torsion
Findings

Sinusoidal Roll Tilt

Ocular Counter-Roll (degree roll / degree tilt)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>0.10</td>
</tr>
<tr>
<td>BLAST</td>
<td>0.15</td>
</tr>
<tr>
<td>BLAST/HEAD INJURY</td>
<td>0.25</td>
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</tbody>
</table>
Assessing Unilateral Damage

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Findings

Veteran with Blast Exposure

Ocular Counter-Roll (degrees)

Time (sec)

Chair Translation (mm)

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Findings

Sinusoidal Roll Tilt

Unilateral Centrifugation

Ocular Counter-Roll (degree roll / degree tilt)

NONE  BLAST  BLAST/HEAD INJURY

NONE  BLAST  BLAST/HEAD INJURY

Best Side
Worst Side

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Findings

Difference in OCR Between Sides (%)

- NONE
- BLAST
- BLAST/HEAD INJURY

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Clinical Relevance

- Long term effects of blast exposure are still not understood
- Vestibular problems may contribute to some of the poorly understood symptoms in returning veterans
- Working on new treatments for vestibular problems
Can we improve vestibular function?
Is noise always a bad thing?
Can Noise Improve a Picture?
Can Noise Improve a Picture?

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Can Noise Improve a Picture?
Does this work in physiological systems?
Stochastic Resonance

- Application of stochastic noise has been shown to demonstrated improvements in detecting weak signals in several sensory systems including crayfish mechanoreceptors (Douglass et al, 1993) and rat cutaneous afferents (Collins et al, 1996).
- Human studies have shown improved signal detection of hippocampal CA1 neurons (Stacey and Durand, 2000) and sensory tactile nerves (Collins et al, 1996).
- Application of stochastic noise galvanic vestibular stimulation has been shown to improve response to a platform perturbation (Pavlik et al, 1999).
Basis of Stochastic Resonance

NEURAL ACTIVITY

Total Nerve Activity (Arbitrary Units)
Basis of Stochastic Resonance

![Diagram showing the basis of stochastic resonance with neural activity and stochastic noise]

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Basis of Stochastic Resonance

![Diagram showing neural activity, stochastic noise, and summed activity](image-url)
Can we improve vestibular function?
Methods

- 20 Veterans (22-71 yrs)
- Ocular Counter Roll measurements made during sinusoidal roll tilt of 25 degrees at 0.03125 Hz, 0.125 Hz, and 0.25 Hz for both control and sub threshold stochastic noise trials.
- Stochastic noise galvanic vestibular stimulation was bipolar
- Veterans also completed Posturography
- Group of subjects also completed tandem stand testing with eyes closed during sham and stimulation trials.
Improvement in Ocular Torsion of Veterans During Stochastic Noise Vestibular Stimulation

![Bar graph showing equilibrium scores for control and stimulation groups at 0.125 Hz tilt. The graph indicates a significant improvement in equilibrium scores for the stimulation group compared to the control group.]

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Does this improvement in ocular counter-roll result in functional improvements?
Improvement in Balance in Group of Veterans During Stochastic Noise Vestibular Stimulation

Equilibrium Score

Eyes Closed on Unstable Surface

Control
Stim

Presented by the VA War Related Illness and Injury Study Center (WRIISC)
Poll Question:

What type of vestibular damage do you think may be more common in mTBI with blast exposure?

1) Unilateral Canal
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3) Bilateral Canal
4) Bilateral Otolith
5) None
Summary

- mTBI may be associated with unilateral otolith damage that may underlie some symptoms
- These deficits may not be found during bilateral tests
- Application of subsensory GVS using a specific noise paradigm can improve VOR and balance
Vestibular Consequences of Mild Traumatic Brain Injury and Blast Exposure

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East Tennessee State University
Johnson City, TN
Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.
Poll Question

What is your primary role in VHA?

1) Clinician
2) VA Researcher
3) Non-VA Researcher
4) Management/policy maker
5) Other
Dizziness and War-Related Injuries

Robert Bárány (1910) association between head injury and dizziness

Caveness & Nielson (1961) reported that 56% of 407 Korean conflict veterans with head injury complained of giddiness & vertigo
Scope of the Problem

15% to 78% patients with head injury report dizziness/vertigo

Symptoms often last for 6 months or longer following the head trauma/blast exposure

Van Campen et al., 1999; Cohen et al. 2002
Overview of Balance System

Sensory Input
- Visual
- Vestibular
- Proprioceptive

Central Processing
- Vestibular Nuclear Complex
- Cerebellum

Motor Output
- Motor Neurons
Vestibular Sensory Organs

Semicircular Canals

Otolith Organs

Utricle

Saccule
Vestibulo-ocular Reflex (VOR)

Vestibular ganglion
Vestibular nucleus
Ocular motor nuclei

Goal is to stabilize gaze during angular head acceleration
Tests of Horizontal Semicircular Canal (hSCC)/Superior Vestibular Nerve Function

- Binaural Bithermal Caloric Test
- Rotary Chair Test (SHA, step velocity)
Ocular Motor Function

Gaze-Evoked Nystagmus
Smooth Pursuit
Saccades
Optokinetic Nystagmus
Fixation Suppression

Abnormalities suggest possible central pathology (brainstem/cerebellar)
Otolith Organs

Utricle and saccule located in vestibule

Stimulus is linear acceleration, tilt, & gravity

otoconia
Benign Paroxysmal Positioning Vertigo (BPPV) and Head Injury

BPPV is a common vestibular disorder associated with head injury

10 – 25% of head trauma patients develop BPPV

Proctor et al., 1956; Barber, 1964; Davies & Luxon, 1995
Mechanism for BPPV: canalithiasis

Free-floating otoconia in the endolymph

Hall, Ruby, & McClure, 1979

Accounts for short duration of vertigo and nystagmus

Basis for modern approaches to treatment

Brandt & Steddin, 1993
Management of BPPV

Canalith Repositioning Therapy

Efficacy rate: 80-100%

Fife et al. 2008
Bhattacharyya et al. 2008
Tests of Otolith Function

Cervical vestibular evoked myogenic potentials
Ocular vestibular evoked myogenic potentials

Subjective visual vertical or ocular torsion
  Centrifugation or tilt
Vestibular Evoked Myogenic Potentials (VEMPs)

Short latency electromyogram evoked by high-level sound or vibration stimuli

Recorded from surface electrodes over the tonically contracted muscles

Cervical VEMP (cVEMP): sternocleidomastoid m.
Ocular VEMP (oVEMP): Inferior oblique extra-ocular m.
Cervical VEMP Recording

Left SCM m. Activation/
Left Ear Stimulation

Air conduction stimulus
500-Hz Tone bursts

Asymmetry Ratio (AR):
100 x (Amp_L – Amp_S) / (Amp_L + Amp_S)
Ocular VEMP Recording

Bone conduction (BC) vibration

Asymmetry Ratio (AR):
\[ 100 \times \frac{\text{Amp}_L - \text{Amp}_S}{\text{Amp}_L + \text{Amp}_S} \]
Vestibulo-Spinal Pathways

Serve to modulate posture

Two components

Medial vestibulo-spinal tract
Lateral vestibulo-spinal tract

Burt, 1993
Balance Testing

Can assess static or dynamic balance function

e.g., Posturography

Sensory Organization Test
Literature Review:
Abnormal vestibular function test findings in individuals with dizziness/imbalance related to TBI/blast exposure

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>hSCC</th>
<th>Otolith organ</th>
<th>Ocular motor</th>
<th>Gait/balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davies &amp; Luxon 1995</td>
<td>100</td>
<td>51%</td>
<td>-</td>
<td>8%</td>
<td>-</td>
</tr>
<tr>
<td>Ernst et al. 2005</td>
<td>63</td>
<td>19%</td>
<td>25%</td>
<td>5%</td>
<td>27%</td>
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<tr>
<td>Dae Lee et al. 2011</td>
<td>28</td>
<td>7%</td>
<td>54%</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Shupak et al. 1993</td>
<td>5</td>
<td>40%</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Van Campen et al. 1999</td>
<td>30</td>
<td>7%</td>
<td>-</td>
<td>7%</td>
<td>37%</td>
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<tr>
<td>Cohen et al. 2002</td>
<td>17</td>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>4%</td>
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<tr>
<td>Scherer et al. 2011*</td>
<td>11</td>
<td>27%</td>
<td>17%</td>
<td>45%</td>
<td>-</td>
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## Mountain Home VAMC study: Preliminary findings

<table>
<thead>
<tr>
<th></th>
<th>TBI/Blast N = 51</th>
<th>Control N = 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>37 (10)</td>
<td>26 (5)</td>
</tr>
<tr>
<td>MMSE</td>
<td>29 (1.8)</td>
<td>30 (.4)</td>
</tr>
<tr>
<td>PTSD</td>
<td>92%</td>
<td>0%</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>98%</td>
<td>14%</td>
</tr>
<tr>
<td>Sensorineural Hearing Loss</td>
<td>67%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Symptom characteristics of mTBI/blast group (n = 51)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertigo</td>
<td>25 (49%)</td>
</tr>
<tr>
<td>Imbalance</td>
<td>45 (88%)</td>
</tr>
<tr>
<td>Lateropulsion</td>
<td>26 (52%)</td>
</tr>
<tr>
<td>Lightheadedness</td>
<td>37 (73%)</td>
</tr>
<tr>
<td>Oscillopsia</td>
<td>3 (6%)</td>
</tr>
</tbody>
</table>
History of blast exposure for 51 Veterans

<table>
<thead>
<tr>
<th>Number of blasts</th>
<th>Number of Veterans</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>1-2</td>
<td>13</td>
</tr>
<tr>
<td>3-5</td>
<td>6</td>
</tr>
<tr>
<td>5+</td>
<td>29</td>
</tr>
</tbody>
</table>

Time since worst exposure

Range = 6 months – 10 years
Mean (SD) = 5 years 9 mos (30 mos)
4 Veterans with symptoms ≥ 20 years
Tests of Central Vestibular Function

- Saccades
- Tracking
- Gaze
- Fixation
- Nystagmus

Normal Findings (%)

- TBI/Blast
- Control
Tests of Peripheral Vestibular Function

- Caloric Test
- Rotary Chair
- oVEMP
- cVEMP

Normal Findings (%)

- hSCC/SVN
- utricle/SVN
- saccule/IVN

*p = 0.014
Further evidence

Histological studies and cVEMP studies in humans and animals suggest that the saccule may be particularly susceptible to noise-related damage.

Kerr & Byrne, 1975; Ylikoski, 1987; Akdogan et al., 2009; Hsu et al., 2008; Fetoni et al., 2009; Wang et al., 2006; Wang & Young, 2007; Akin et al. 2012
Tests of Gait and Balance

Normal Findings (%)

* p ≤ 0.01

SOT  DGI  FAP  Gait Velocity

TBI/Blast  Control
Case Study: History

• 22 year old male c/o imbalance and lightheadedness with onset 1 year ago
• Hx of > 300 blast exposures (security for explosive ordnance clearance team)
• Diagnosed with mTBI and PTSD
• Noise-induced sensorineural hearing loss worse AD and constant tinnitus AU
Case Study: Ocular Motor Test Results

No gaze evoked or spontaneous nystagmus
Saccades WNL
Tracking WNL
Normal fixation suppression
Case Study: hSCC Tests Results

Bithermal Binaural Caloric Test

Caloric nystagmus symmetrical and WNL

Rotary Chair Test

VOR Summary

WNL
Case Study: Otolith Organ Test Results

Cervical VEMPs (AC)

Ocular VEMPs (BC)

Absent cVEMP on the right side
Right saccule/IVN dysfunction

Symmetrical oVEMPs
WNL
Case Study: Balance & Gait Tests

Sensory Organization Test

- Dynamic Gait Index = 19 (abnormal)
- Functional Ambulation Profile = 88 (abnormal)
- Gait velocity = 63 cm/s (abnormal)
Future Directions

• Consider otolith assessment in individuals with dizziness following mTBI/blast

• Functional consequences
  – Relationship b/w vestibular findings and functional impact

• Rehabilitation?
  – Vestibular exercises (gaze stability) based on VOR (hSCC) dysfunction

• CNS abnormalities (imaging)
References Cited


Further Reading

Acknowledgements

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