Diagnosis and Treatment of Vestibular Disorders in mTBI

Jorge M Serrador, PhD

Associate Professor

[1]*War Related Illness & Injury Study Center, Veterans Administration, East Orange, NJ, USA*

[2]*Dept of Pharmacology & Physiology, Rutgers Biomedical Health Sciences, Newark, NJ, USA*

[3]*Electrical & Electronic Engineering, National University of Ireland Galway, Ireland*

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?

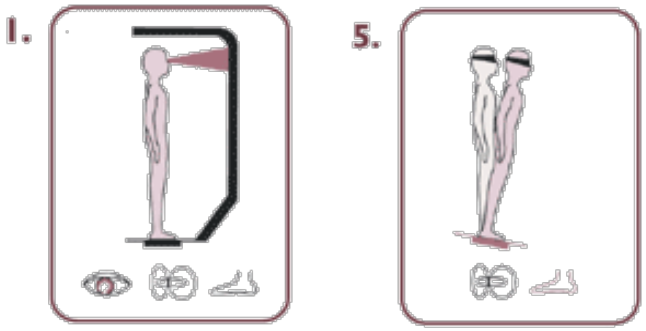
Acute Vestibular Disorder

Chronic Vestibular Disorder

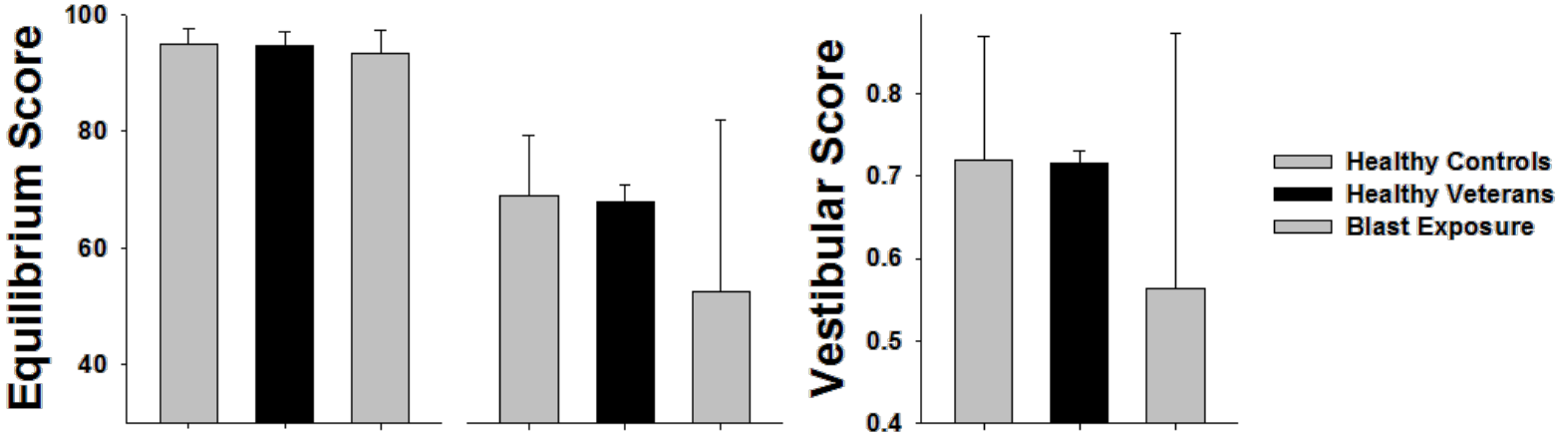
Research Approach

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

Postural Sway in Veterans

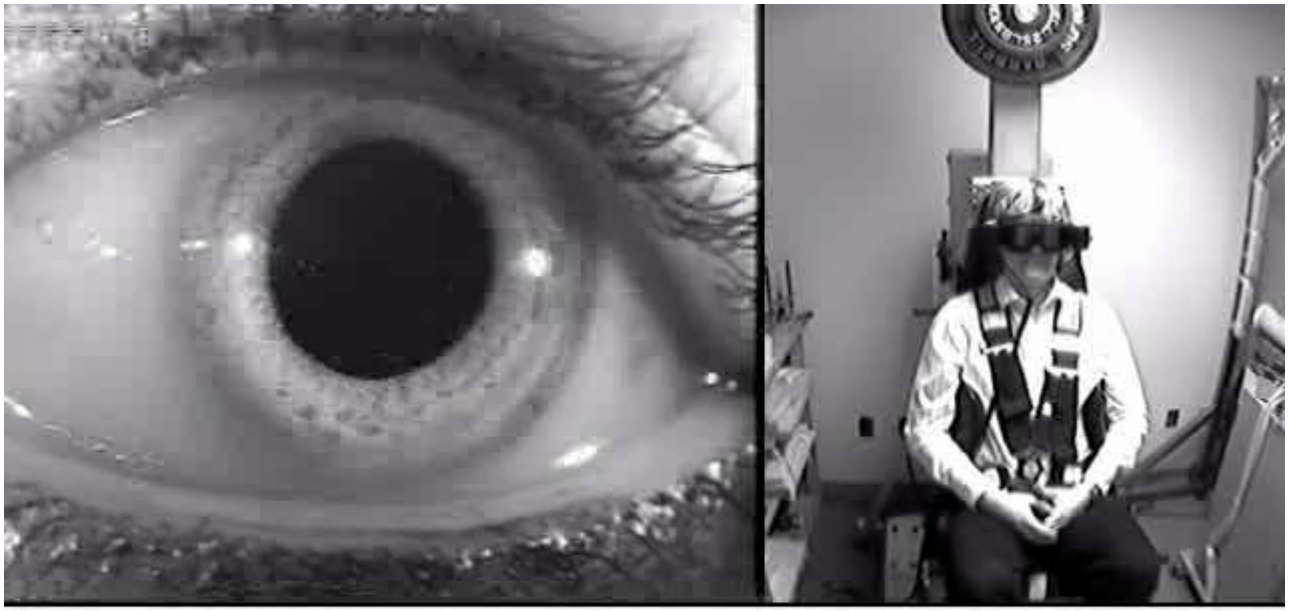


Condition 1 Condition 5

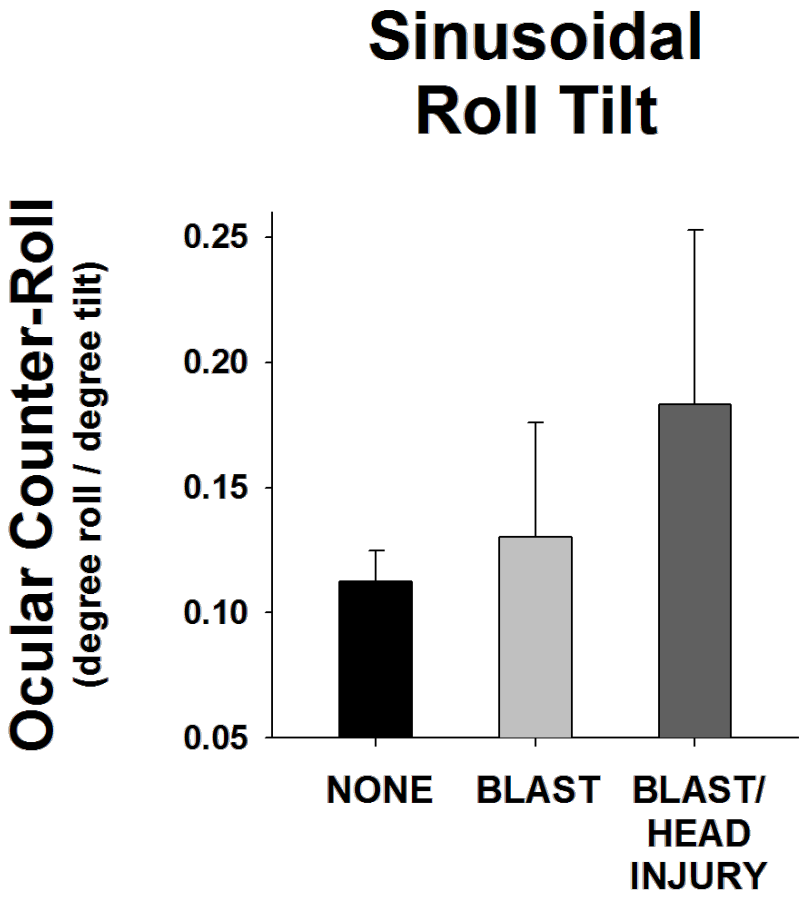


Assessing Ocular Torsion

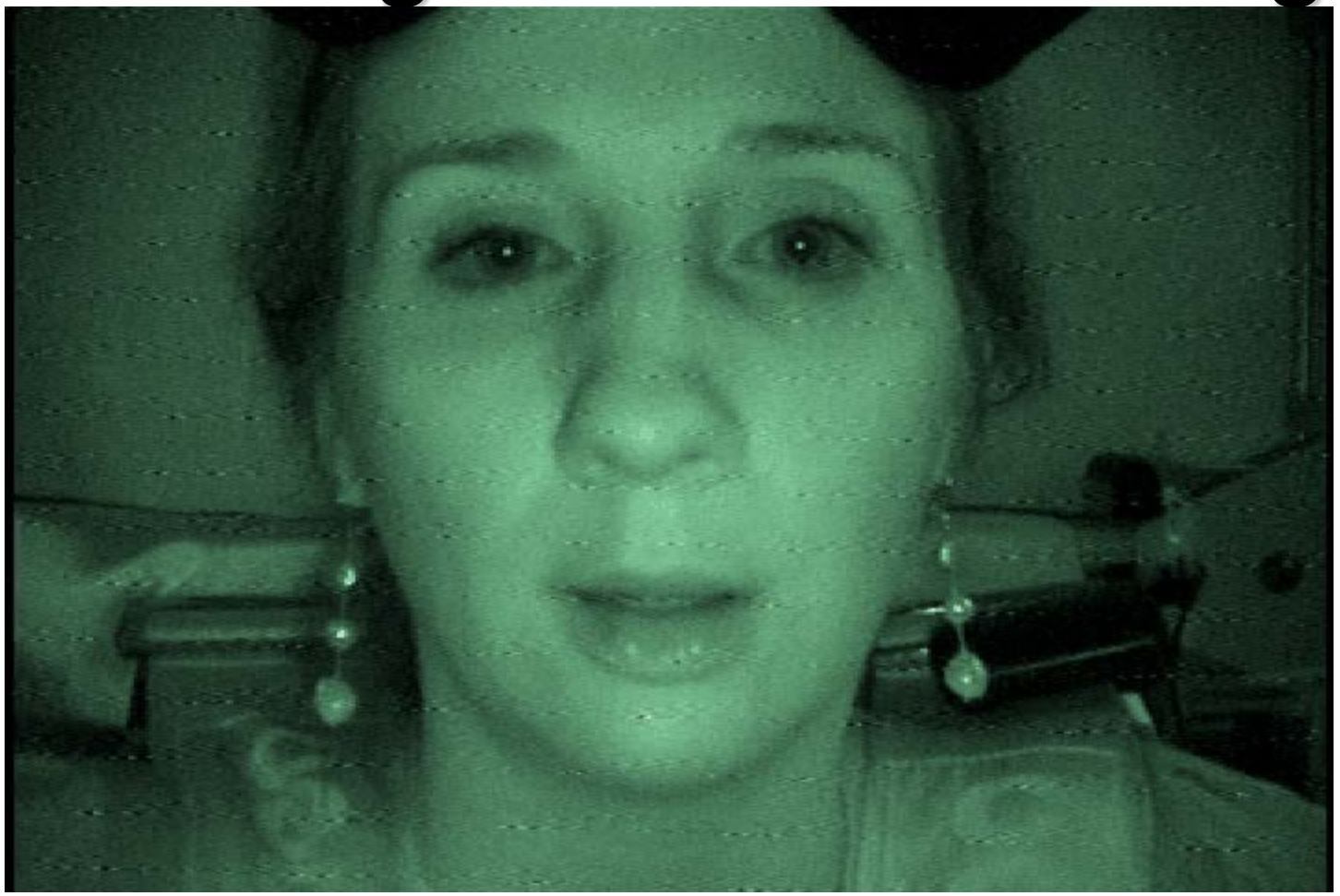
Assessing Otolith Function



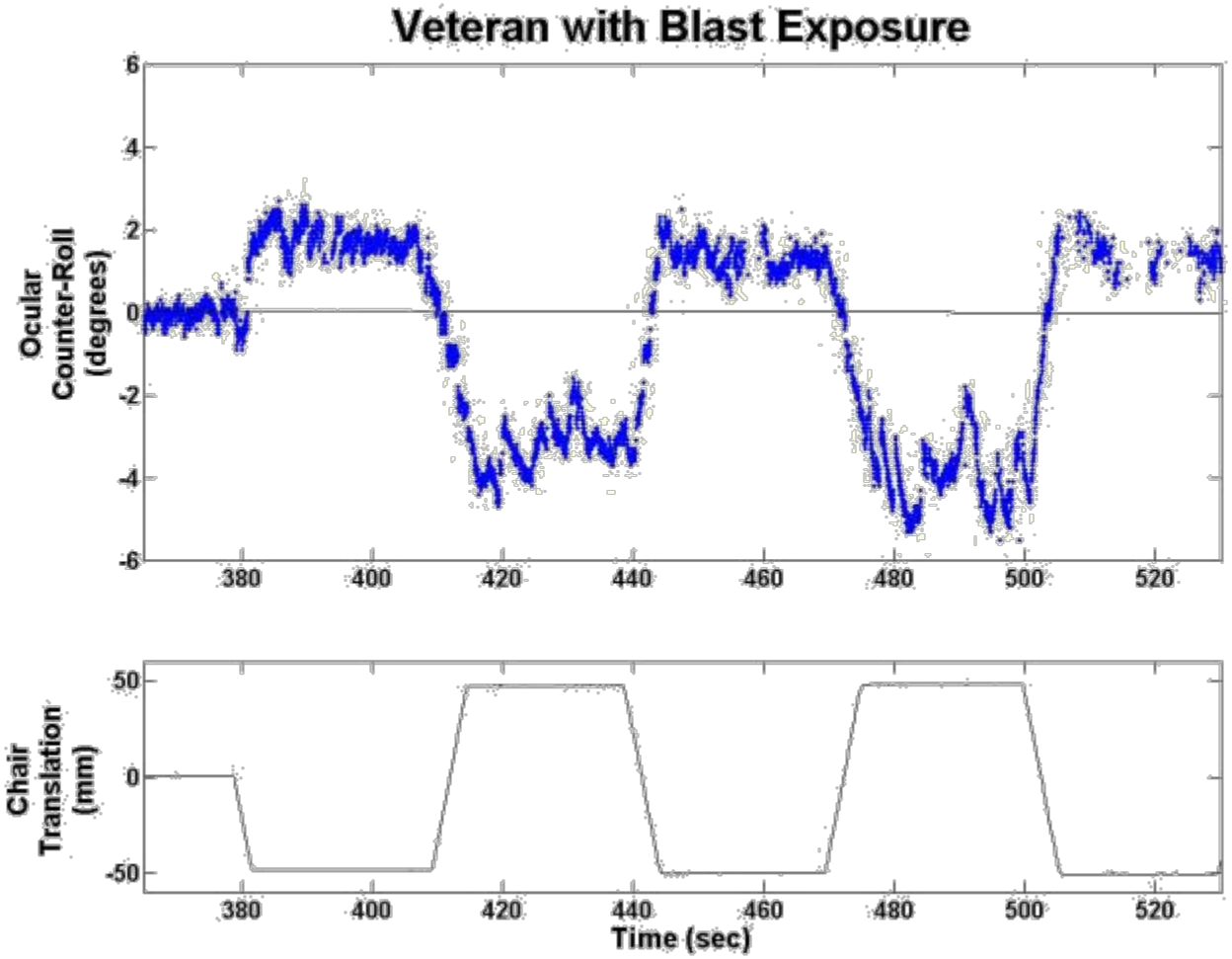
Findings


Sinusoidal
Roll Tilt
Ocular Counter-Roll
(degree roll / degree tilt)
0.25
0.20
0.15
0.10
0.05
NONE
BLAST
BLAST/
HEAD
INJURY

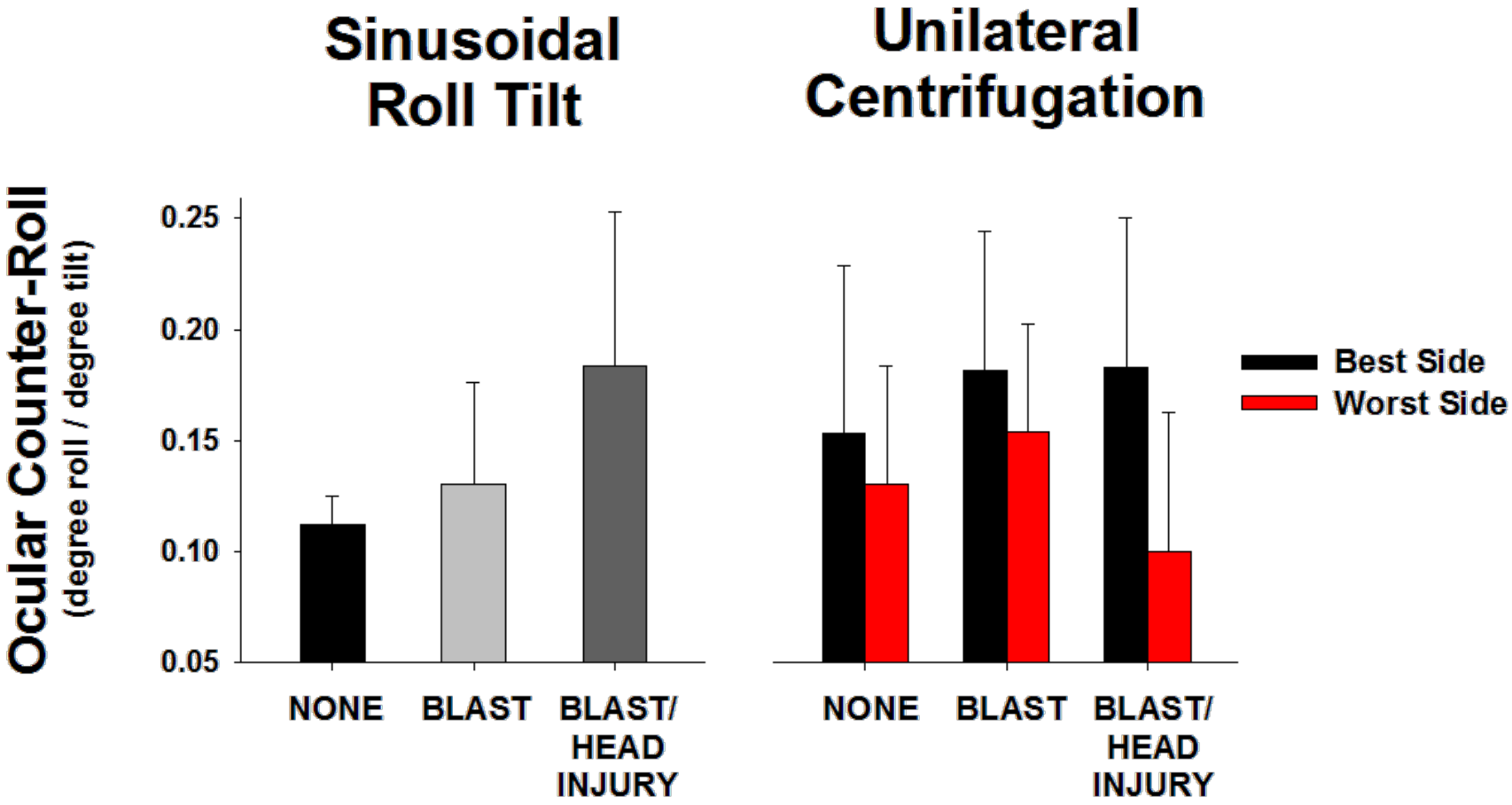
Assessing Unilateral Damage



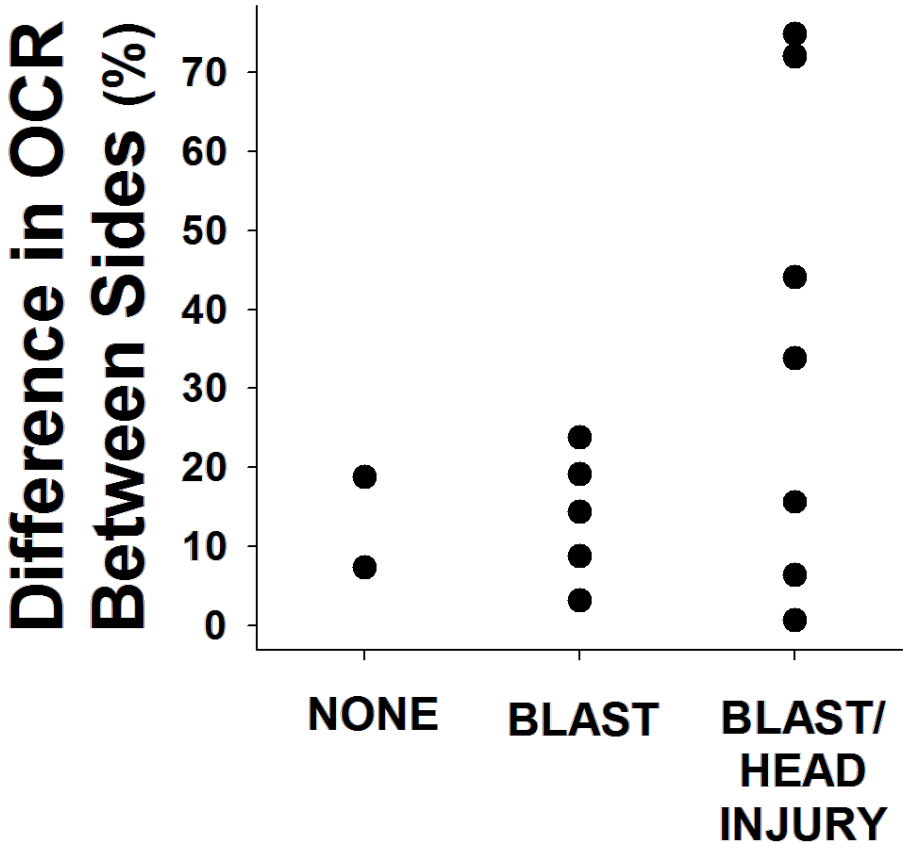
Findings


Veteran with Blast Exposure
Ocular Counter-Roll (degrees)
6
4
2
0
-2
-4
-6
380
400
420
440
460
480
500
520
Chair Translation (mm)
50
0
-50
Time (sec)

Findings


Sinusoidal Roll Tilt
Unilateral Centrifugation
Ocular Counter-Roll
(degree roll / degree tilt)
0.25
0.20
0.15
0.10
0.05
NONE
BLAST
BLAST/ HEAD INJURY
NONE
BLAST
BLAST/ HEAD INJURY
Best Side
Worst Side

Findings


Difference in OCR Between Sides (%)
70
60
50
40
30
20
10
0
NONE
BLAST
BLAST/ HEAD INJURY

Clinical Relevance

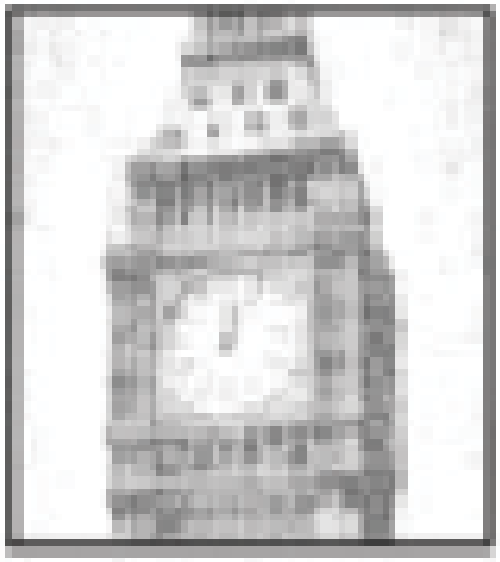
- Long term effects of blast exposure are still not understood
- Vestibular problems may contribute to some of the poorly understood symptoms in returning veterans
- Working on new treatments for vestibular problems

Can we improve vestibular function?

Is noise always a bad thing?

Can Noise Improve a Picture?

Can Noise Improve a Picture?



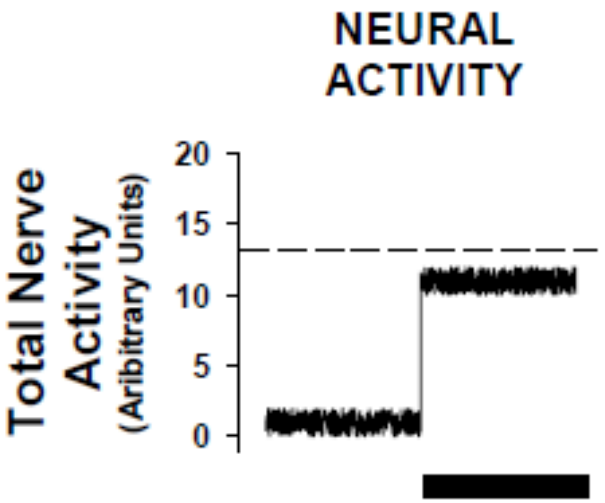
Can Noise Improve a Picture?

Does this work in physiological systems?

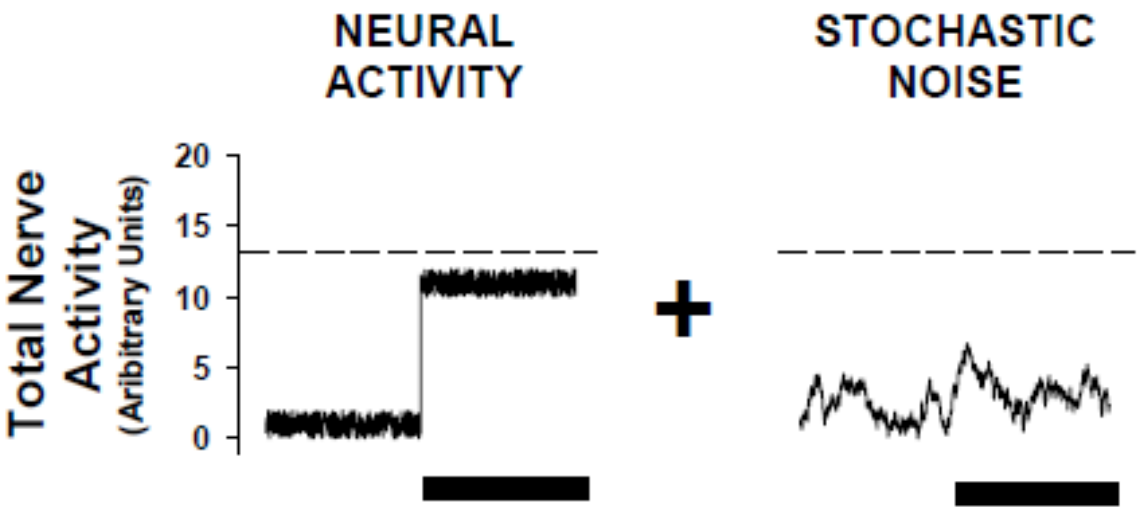
Stochastic Resonance

- ***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)***

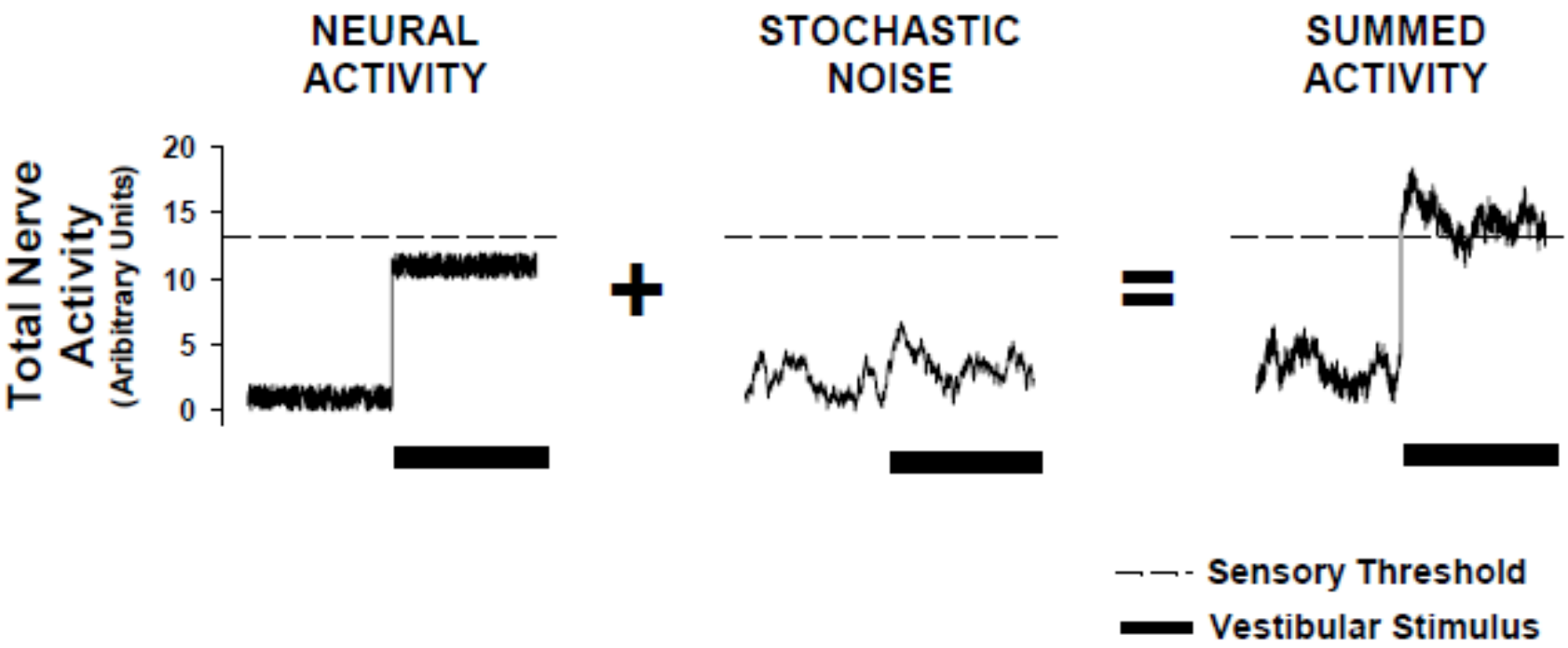
Basis of Stochastic Resonance



Basis of Stochastic Resonance

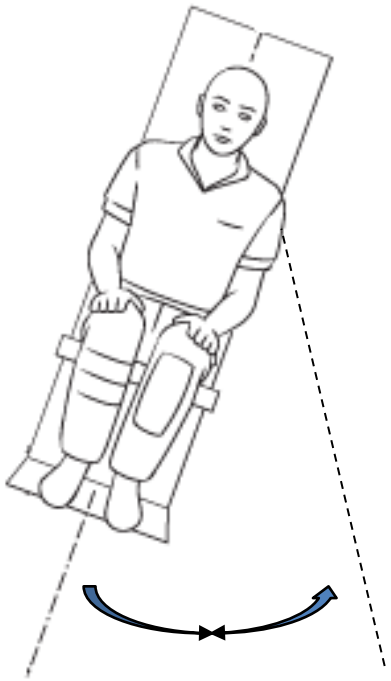


Basis of Stochastic Resonance

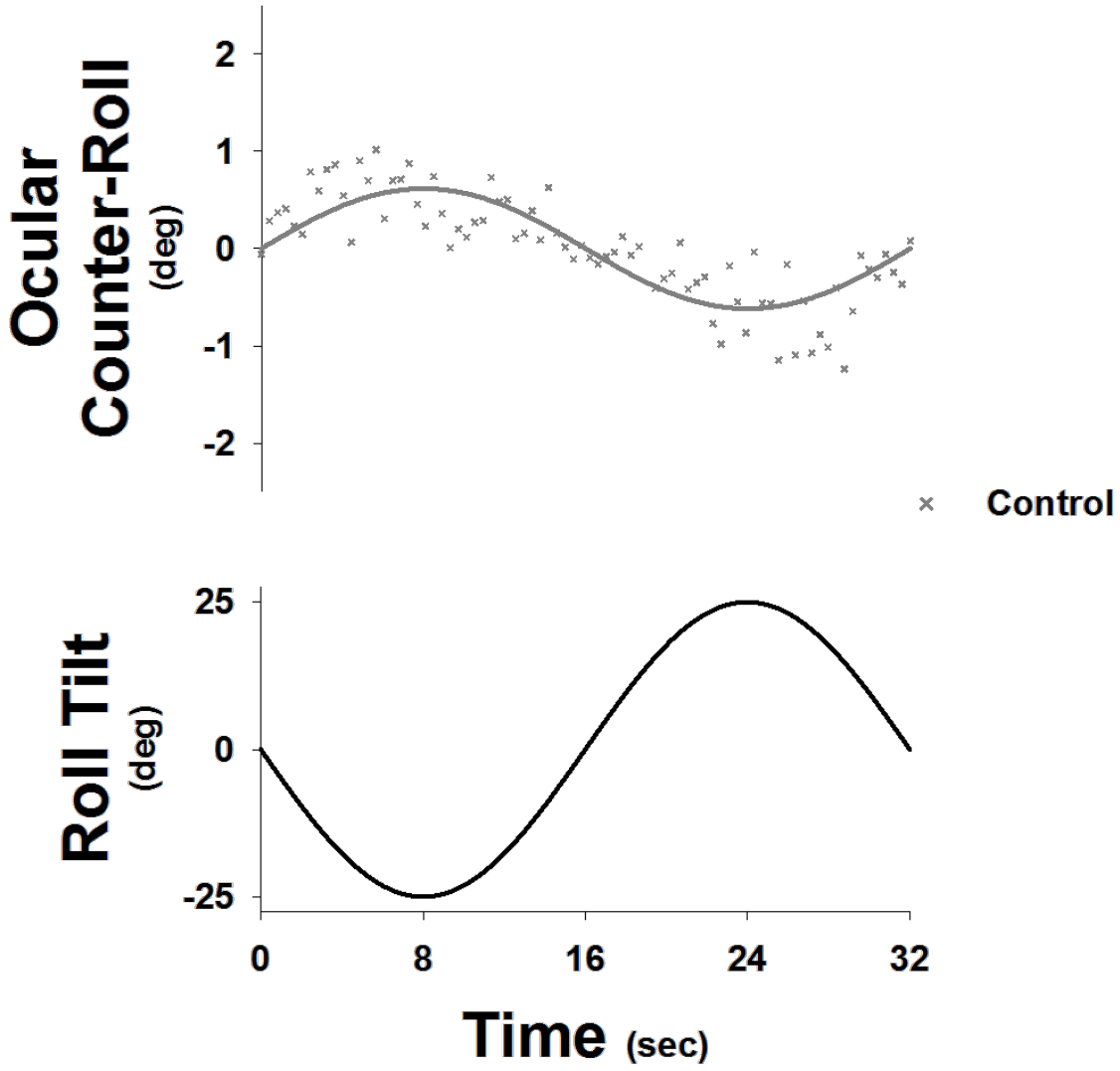


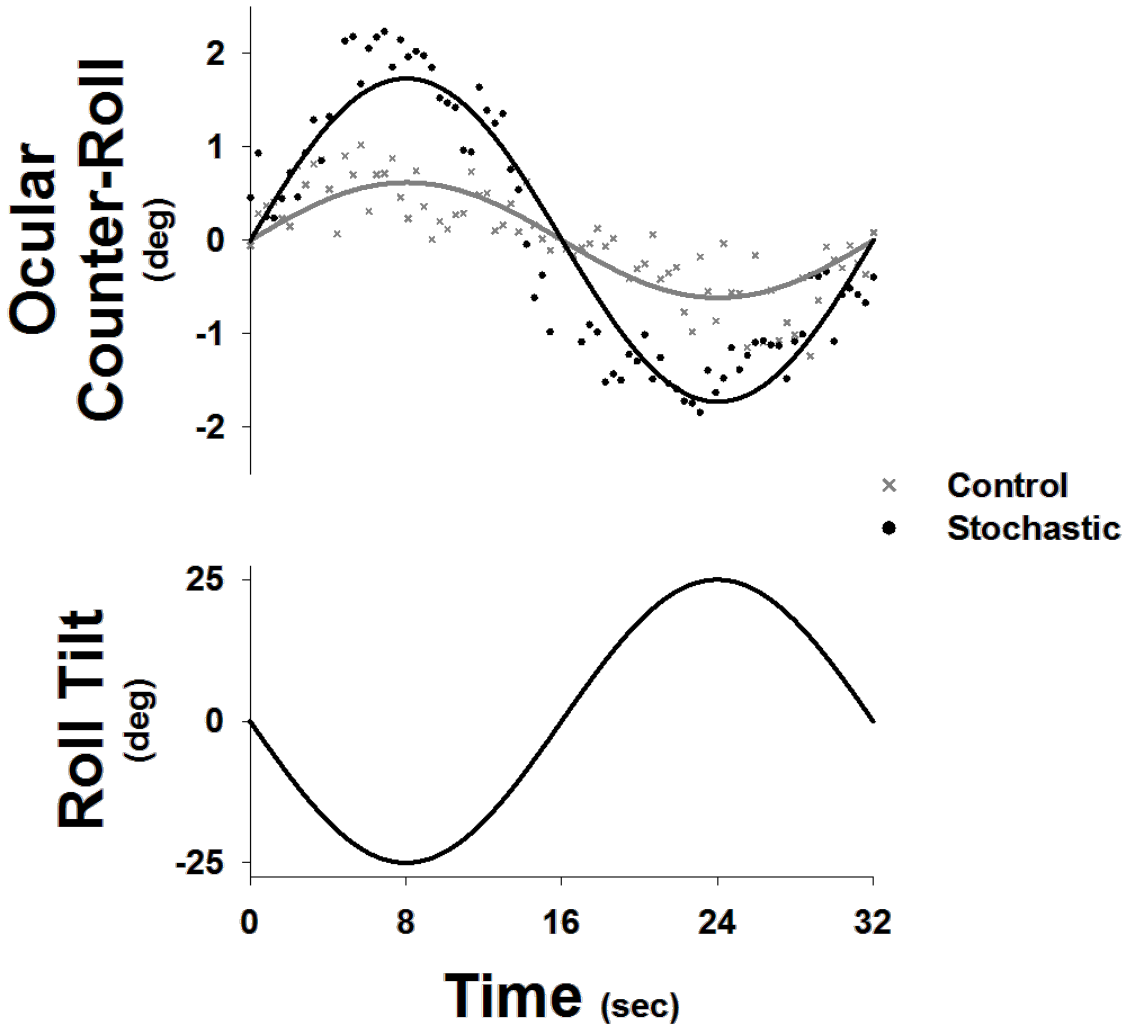
Can we improve vestibular function?

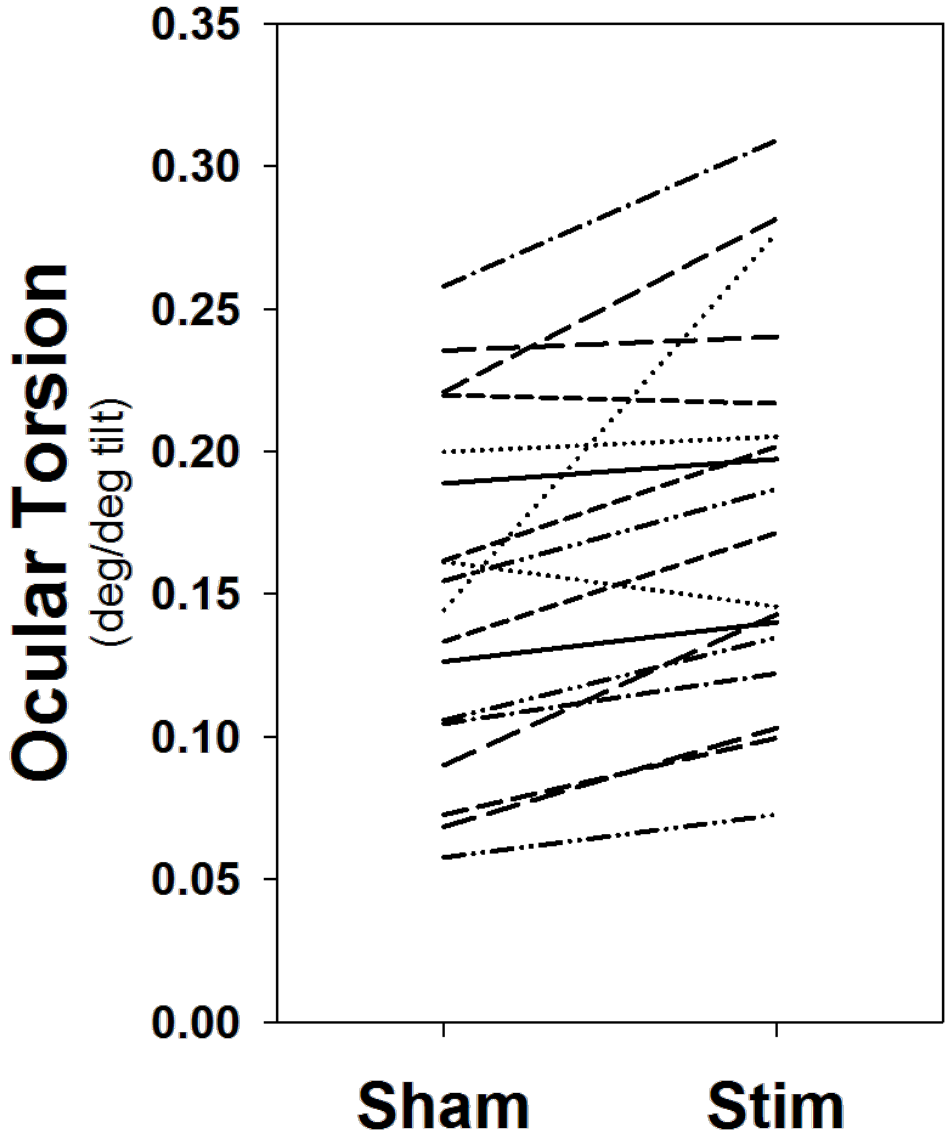
Methods



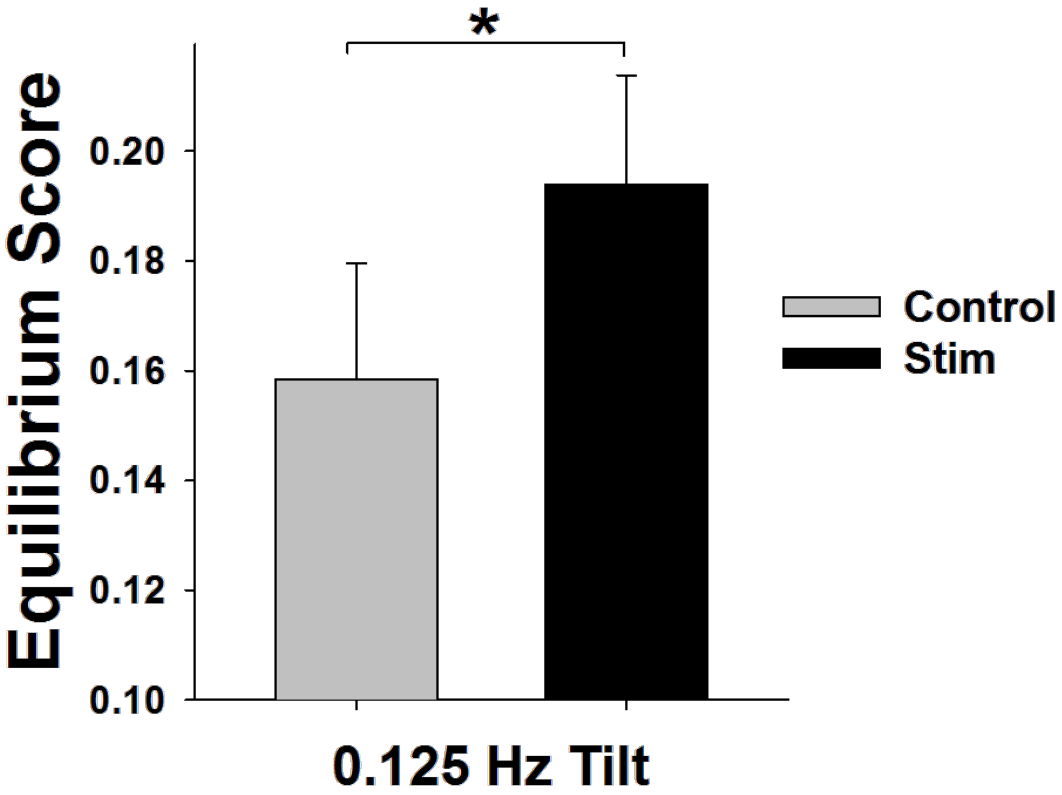
- 20 Veterans (22-71 yrs)
- Ocular Counter Roll measurements made during sinusoidal roll tilt of 25 degrees at 0.03125 Hz, 0.125 Hz, and 0.25 Hz for both control and sub threshold stochastic noise trials.
- Stochastic noise galvanic vestibular stimulation was bipolar
- Veterans also completed Posturography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


Ocular Counter-Roll (deg)
2
1
0
-1
-2
Control
Roll Tilt (deg)
25
0
-25
0
8
16
24
32
Time (sec)

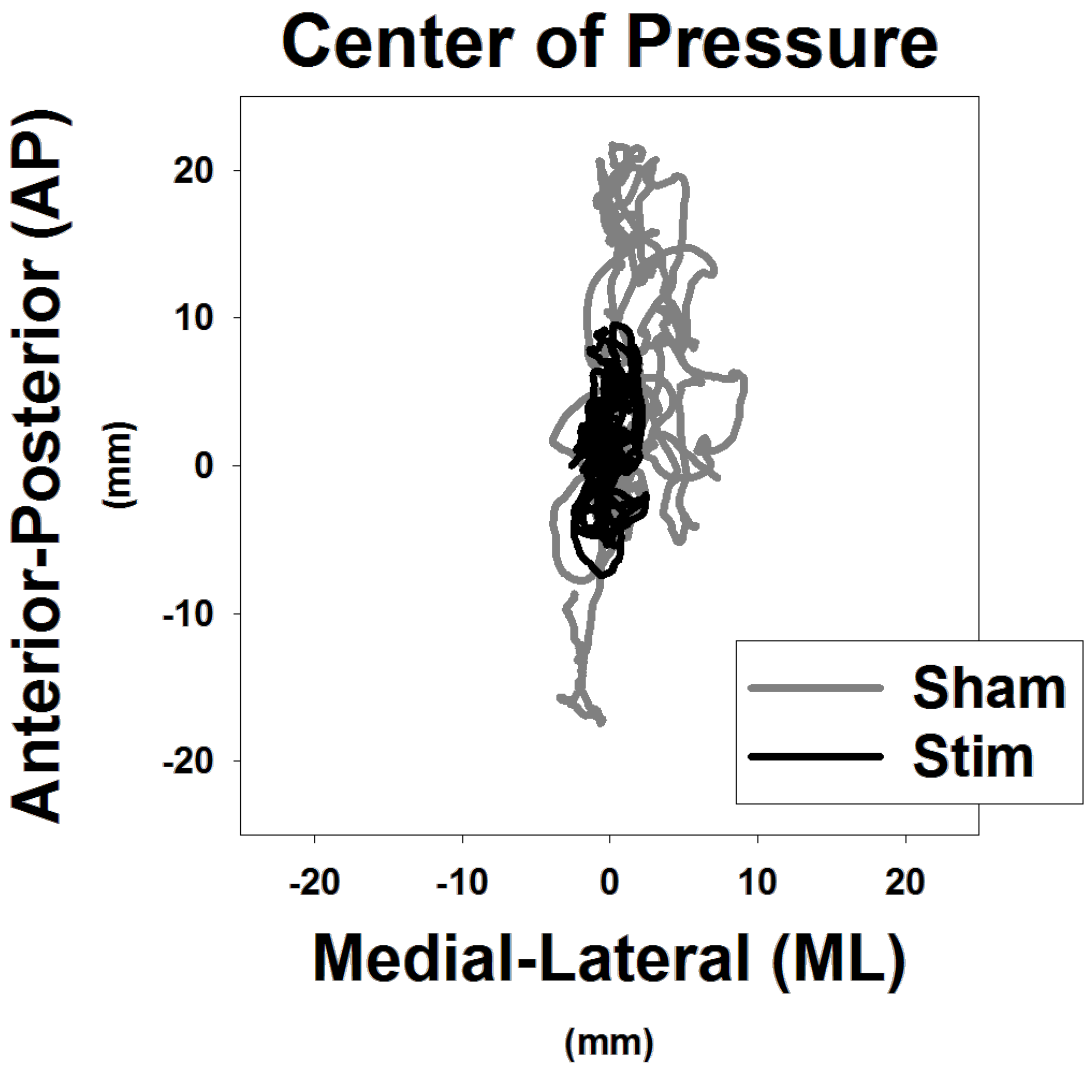

Ocular Counter-Roll (deg)
2
1
0
-1
-2
Control
Stochastic
Roll Tilt (deg)
25
0
-25
0
8
16
24
32
Time (sec)


Ocular Torsion
(deg/deg tilt)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Sham
Stim

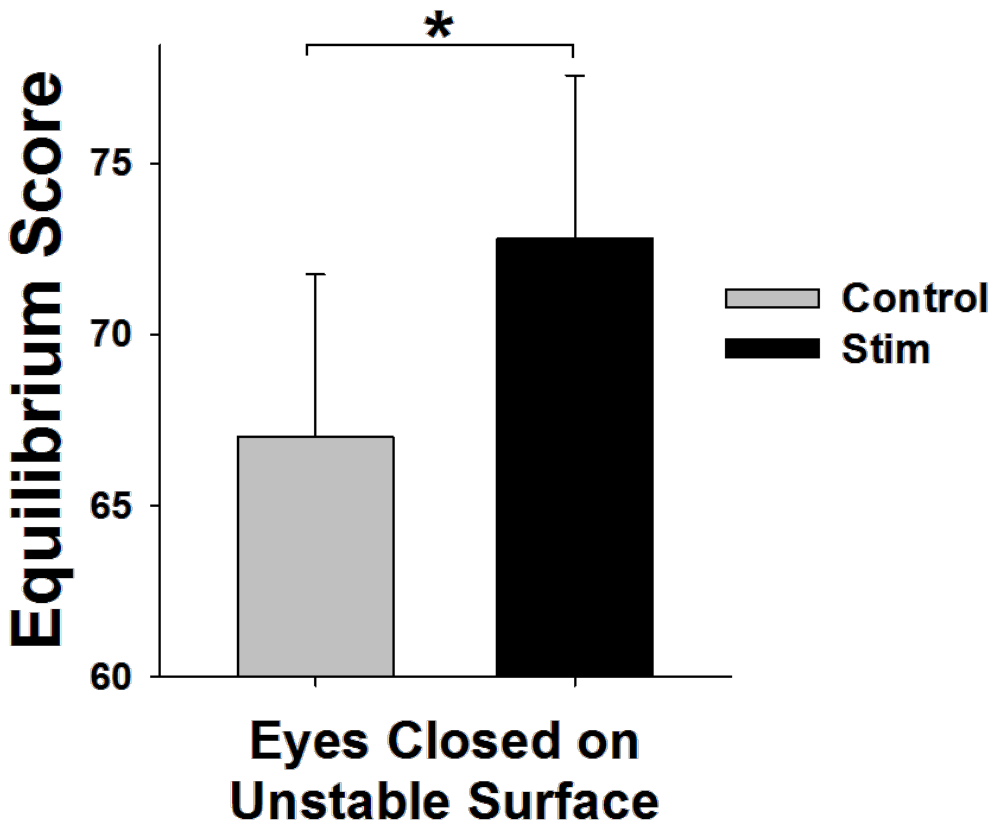
Improvement in Ocular Torsion of Veterans During Stochastic Noise Vestibular Stimulation

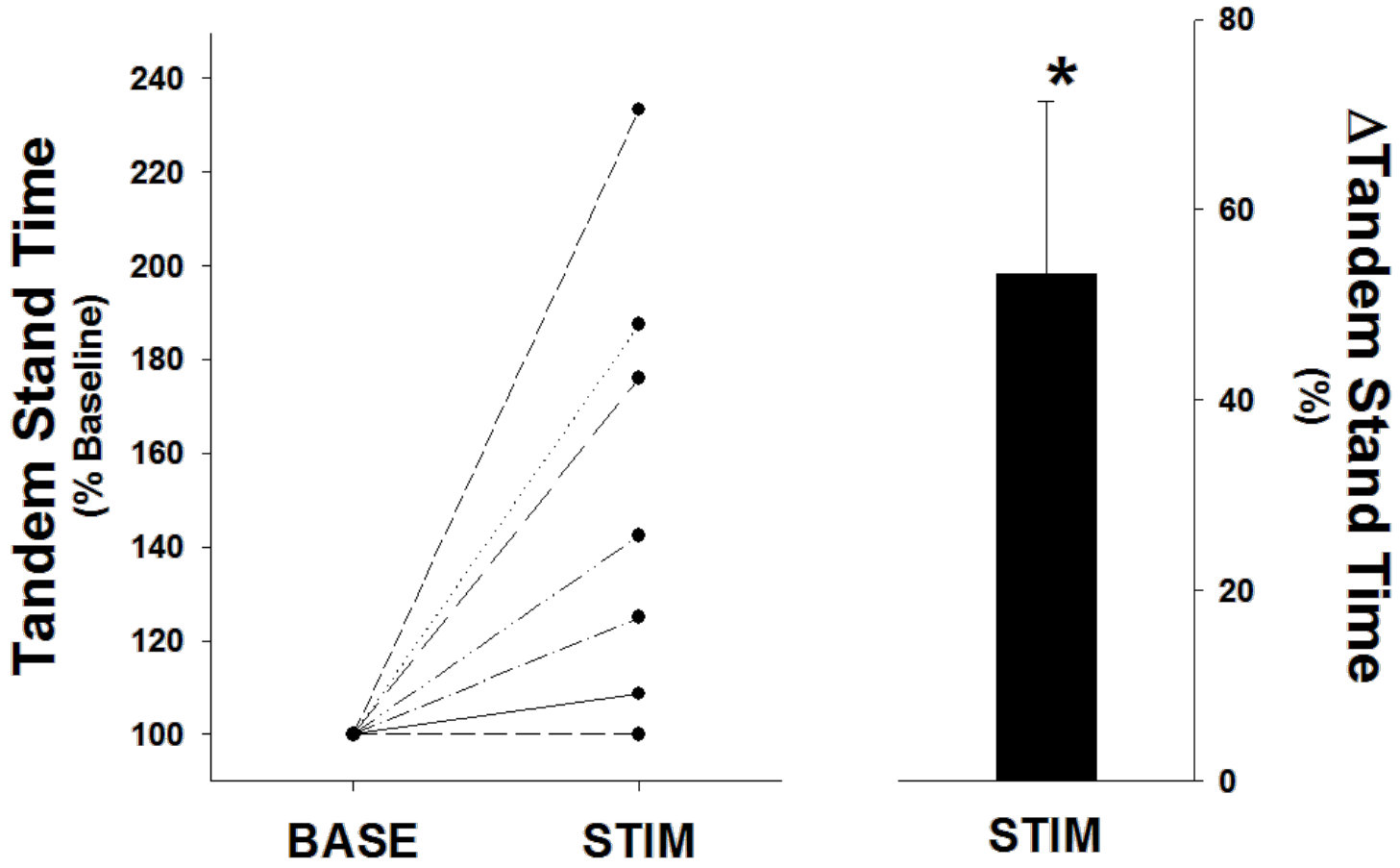


Does this improvement in ocular counter-roll result in functional improvements?


Center of Pressure
Anterior-Posterior (AP)
(mm)
20
10
0
-10
-20
-20
-10
0
10
20
Medial-Lateral (ML)
(mm)
Sham
Stim

Improvement in Balance in Group of Veterans During Stochastic Noise Vestibular Stimulation




Tandem Stand Time
(% Baseline)
240
220
200
180
160
140
120
100
BASE
STIM
*
80
60
40
20
0
STIM
ΔTandem Stand Time
(%)

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

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

Faith W. Akin, Ph.D.
VA Medical Center
Mountain Home, TN

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.

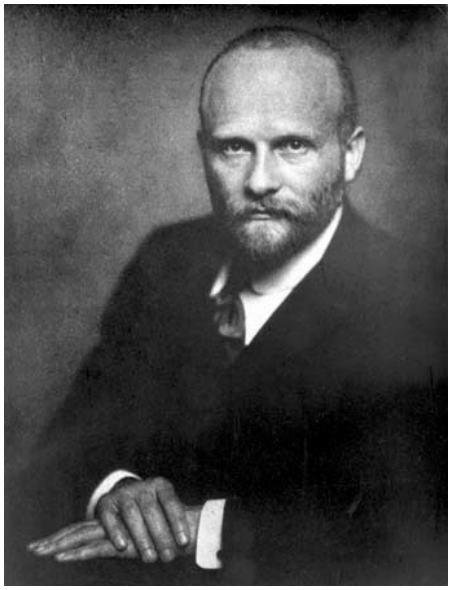
Poll Question

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

Central Processing

Motor Output

Visual

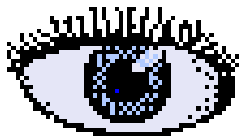
Vestibular

Proprioceptive

Vestibular Nuclear Complex

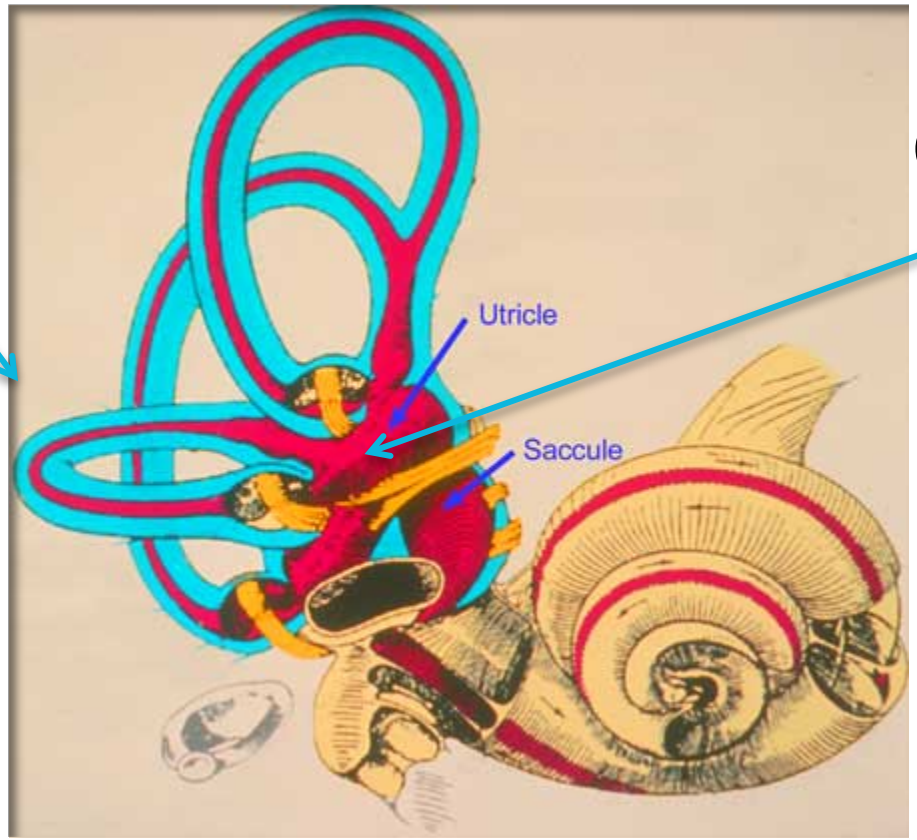
Cerebellum

Motor Neurons



Vestibular Sensory Organs

Semicircular Canals

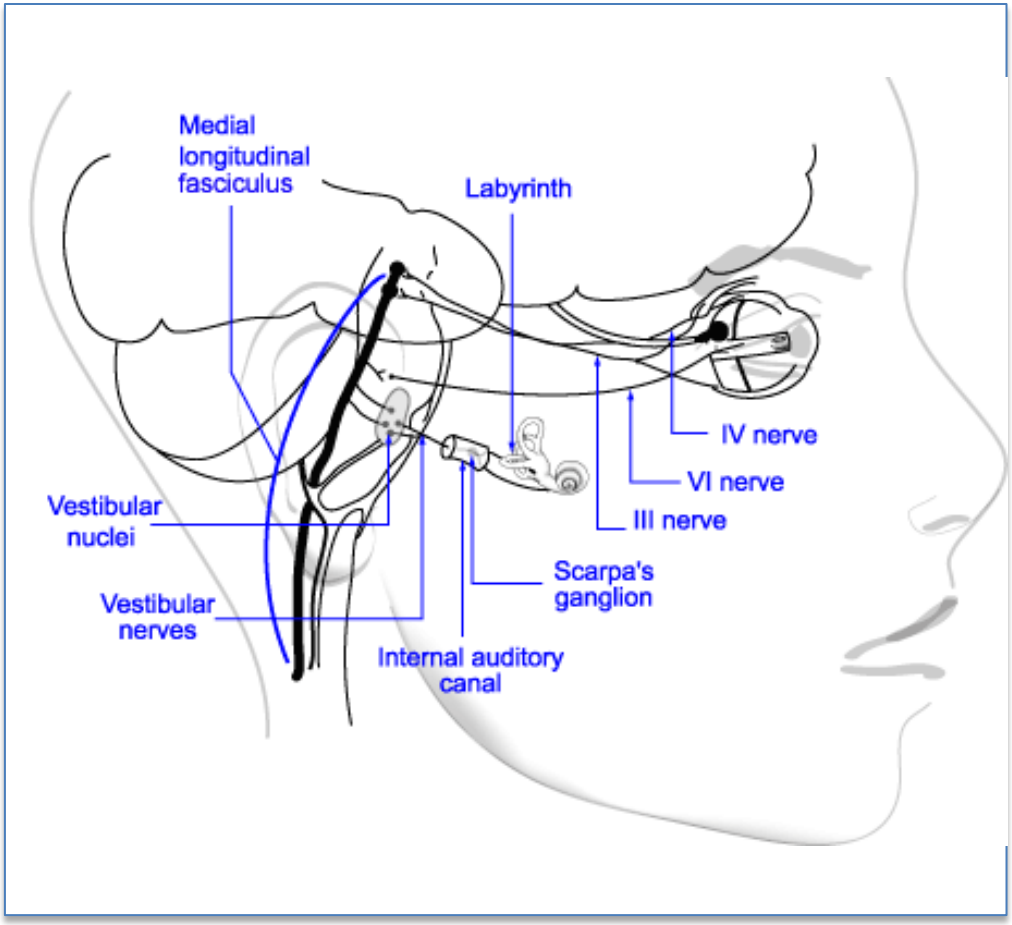


Otolith Organs

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

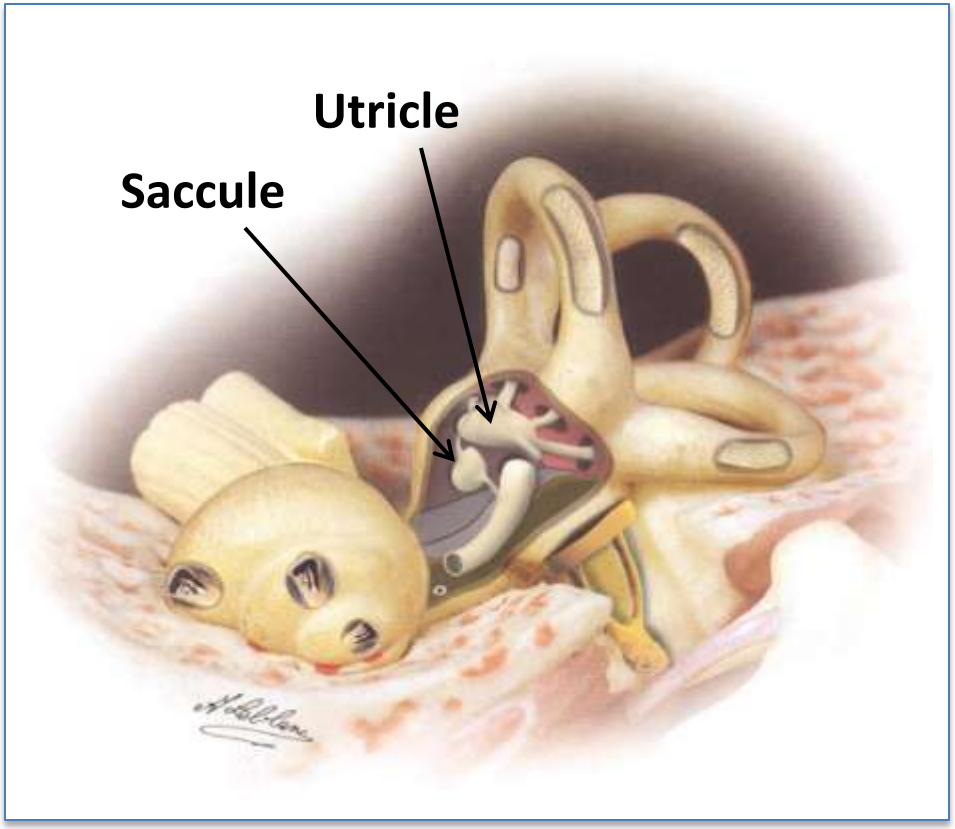
Fixation Suppression

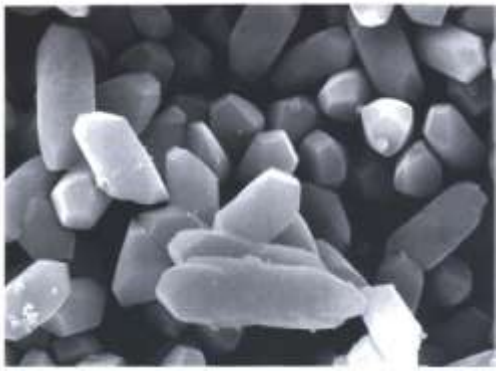
- Abnormalities suggest possible central pathology (brainstem/cerebellar)

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

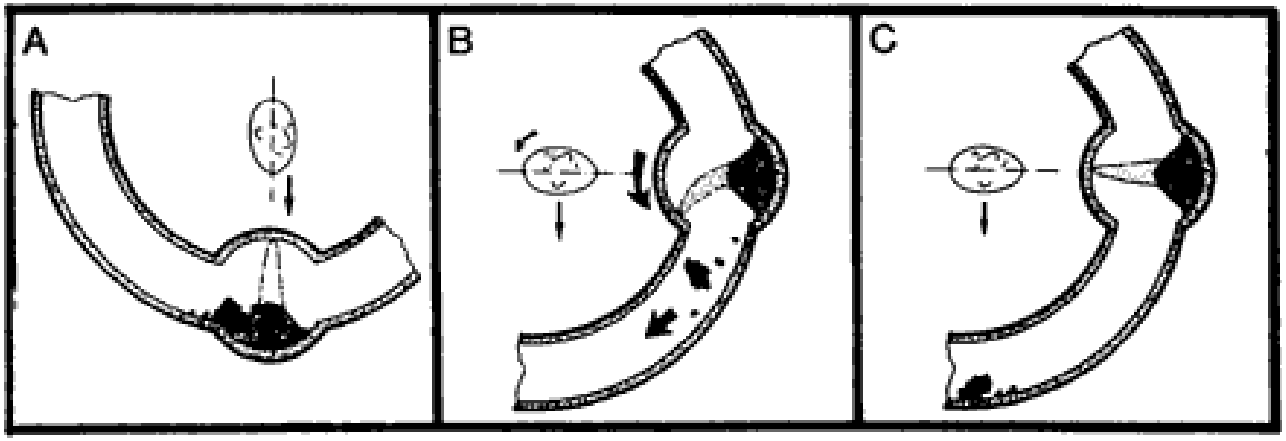
Mechanism for BPPV: canalithiasis

Free-floating otoconia in the endolymph

Hall, Ruby, & McClure, 1979

Accounts for short duration of vertigo and nystagmus

Basis for modern approaches to treatment



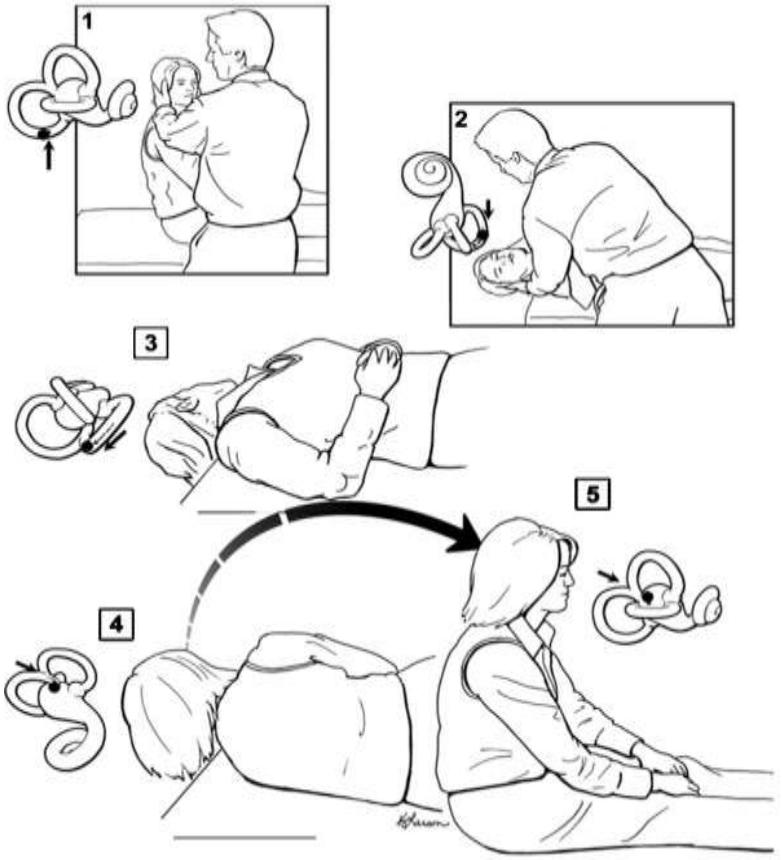
Brandt & Steddin, 1993

Management of BPPV

Canalith Repositioning Therapy

Efficacy rate: 80-100%

- Fife et al. 2008
- Bhattacharyya et al. 2008



Fife, 2009

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

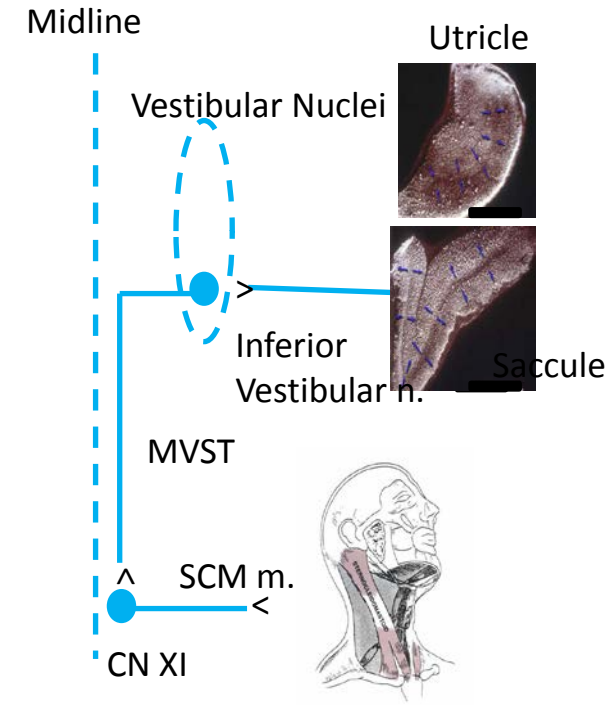
- Cervical VEMP (cVEMP): sternocleidomastoid m.
- Ocular VEMP (oVEMP): Inferior oblique extra-ocular m.

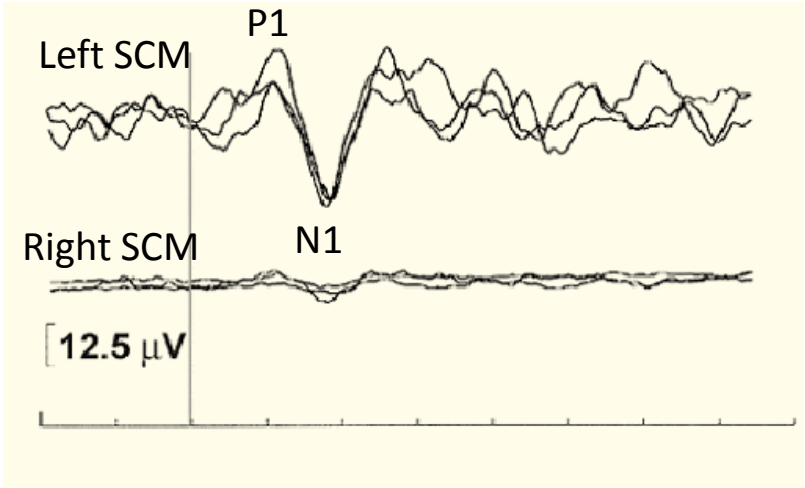
Cervical VEMP Recording

Left SCM m. Activation/
Left Ear Stimulation

Air conduction stimulus
500-Hz Tone bursts

Cervical VEMP Pathway



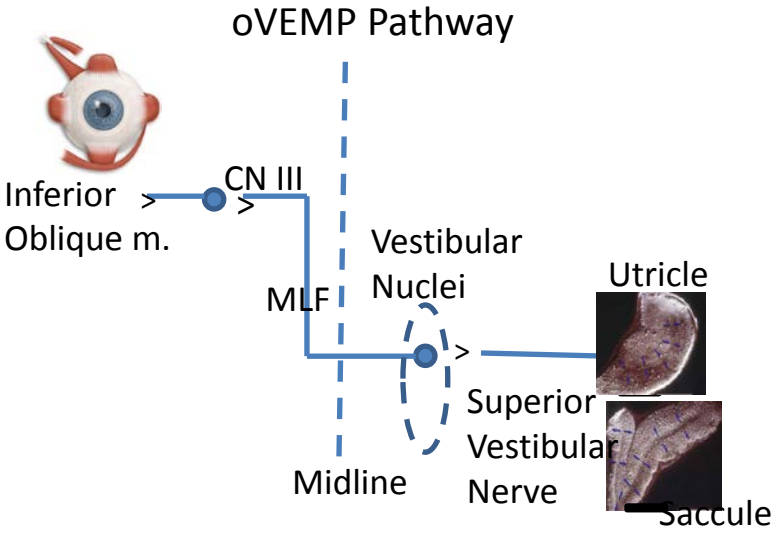


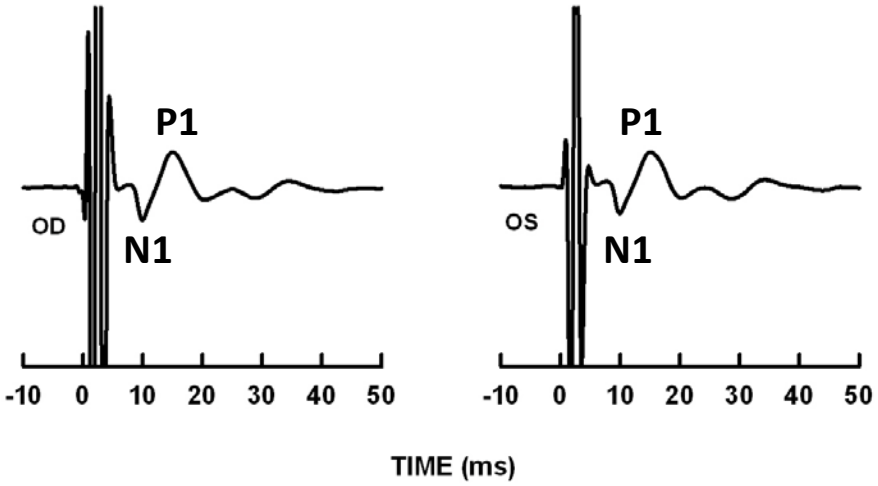
Asymmetry Ratio (AR):

$100 \times (Amp_L - Amp_S) / (Amp_L + Amp_S)$

Ocular VEMP Recording

Bone conduction (BC) vibration





Asymmetry Ratio (AR):

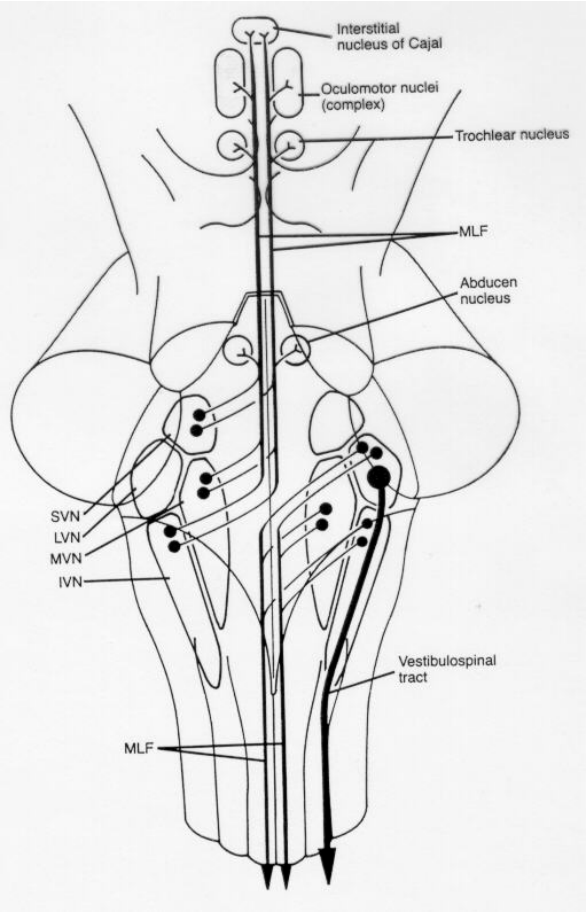
$100 \times (Amp_L - Amp_S) / (Amp_L + Amp_S)$

Vestibulo-Spinal Pathways

Serve to modulate posture

Two components

- Medial vestibulo-spinal tract
- Lateral vestibulo-spinal tract



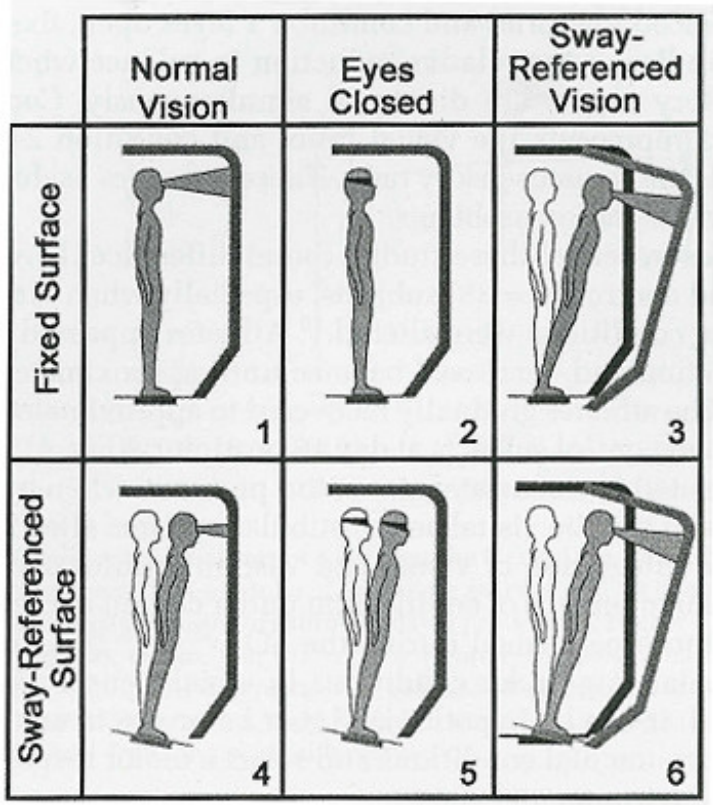
Burt, 1993

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

	N	hSCC	Otolith organ	Ocular motor	Gait/ balance
Davies & Luxon 1995	100	51%	-	8%	-
Ernst et al. 2005	63	19%	25%	5%	27%
Dae Lee et al. 2011	28	7%	54%	-	-
Shupak et al. 1993	5	40%	-	-	-
Van Campen et al. 1999	30	7%	-	7%	37%
Cohen et al. 2002	17	0%	-	-	4%
Scherer et al. 2011*	11	27%	17%	45%	-

Mountain Home VAMC study: Preliminary findings

	TBI/Blast N = 51	Control N = 21
Age	37 (10)	26 (5)
MMSE	29 (1.8)	30 (.4)
PTSD	92%	0%
Tinnitus	98%	14%
Sensorineural Hearing Loss	67%	0%

Symptom characteristics of mTBI/blast group (n = 51)

Symptom	N (%)
Vertigo	25 (49%)
Imbalance	45 (88%)
Lateropulsion	26 (52%)
Lightheadedness	37 (73%)
Oscillopsia	3 (6%)

History of blast exposure for 51 Veterans

Number of blasts	Number of Veterans
0	3
1-2	13
3-5	6
5+	29

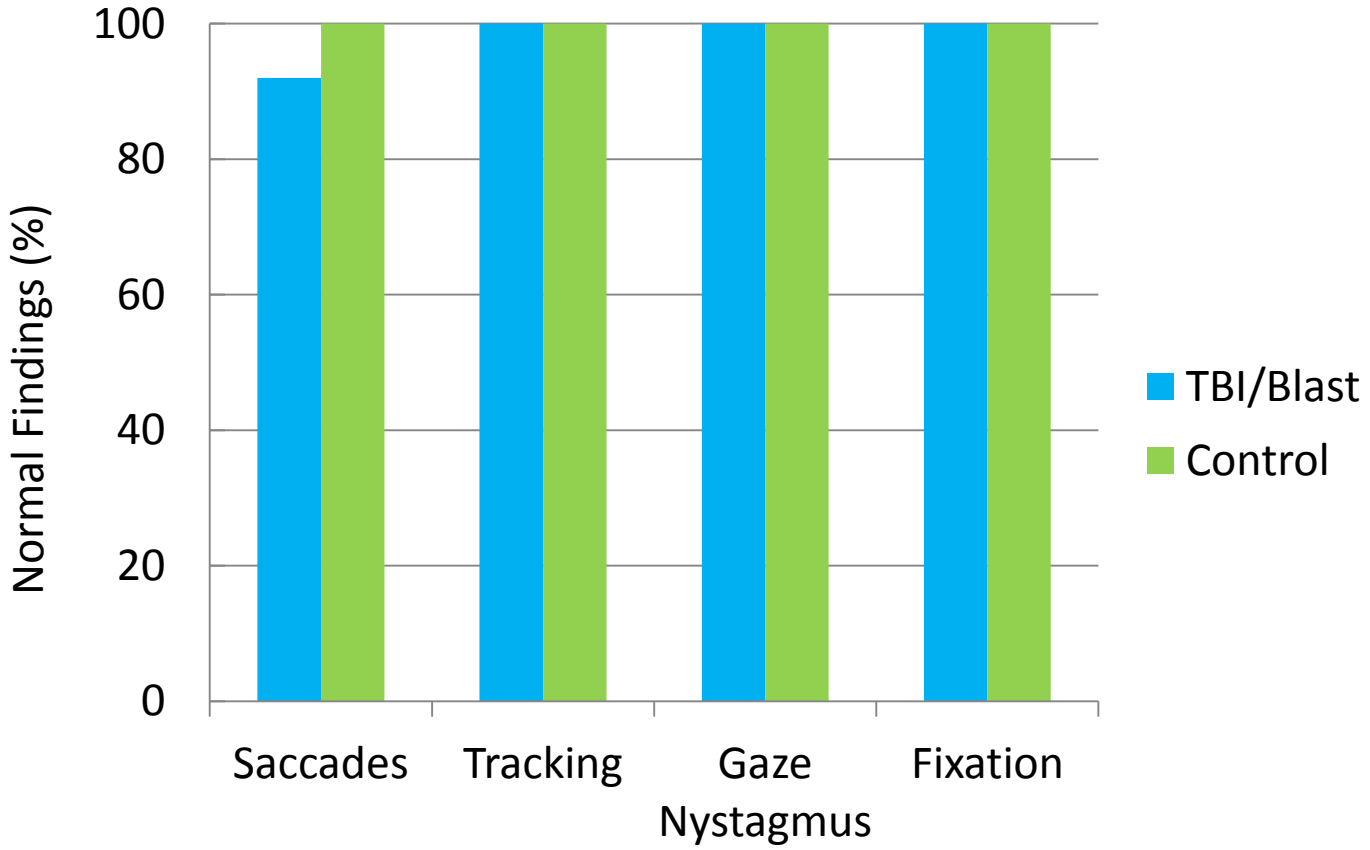
Time since worst exposure

Range = 6 months – 10 years

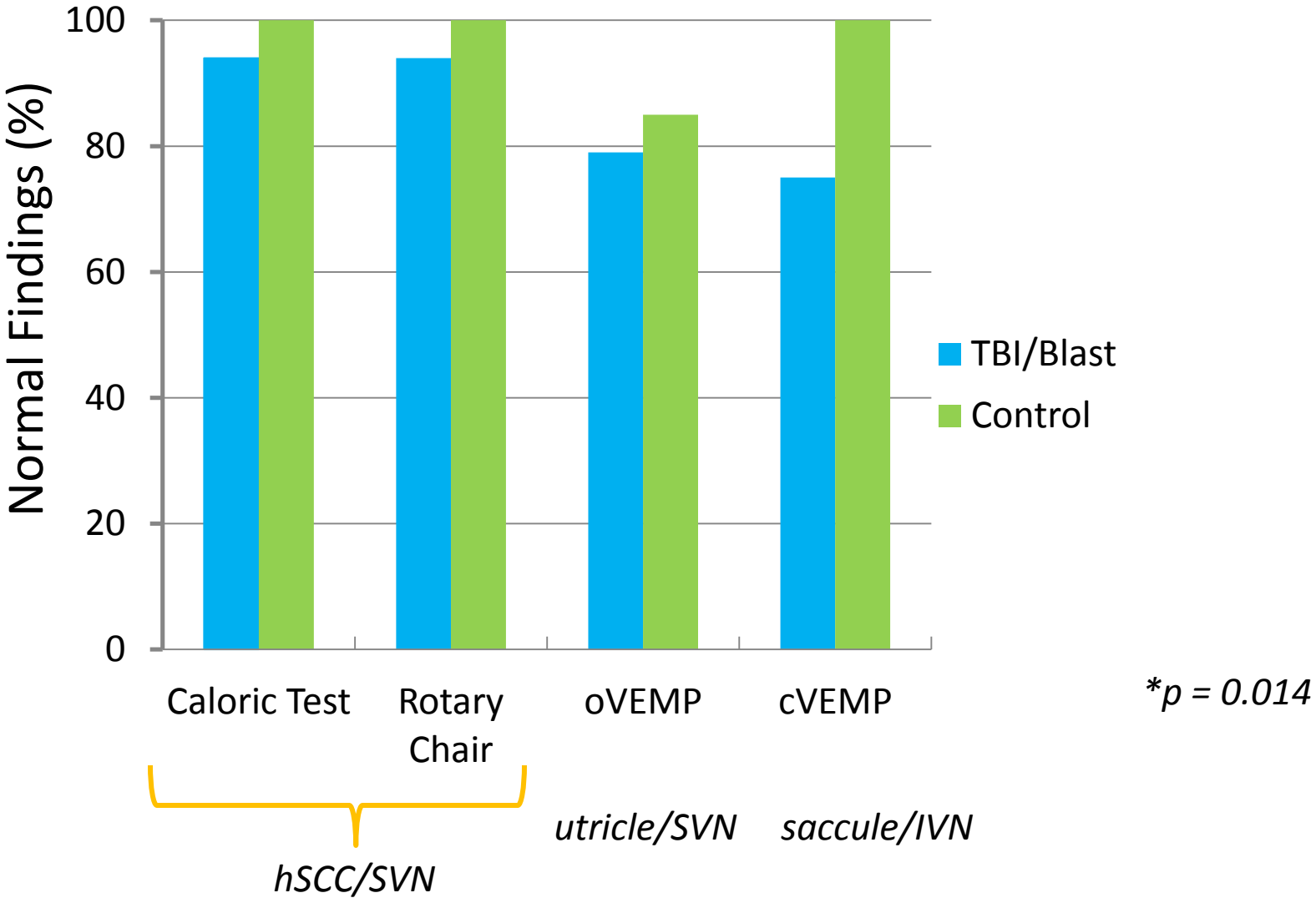
Mean (SD) = 5 years 9 mos (30 mos)

4 Veterans with symptoms ≥ 20 years

Tests of Central Vestibular Function



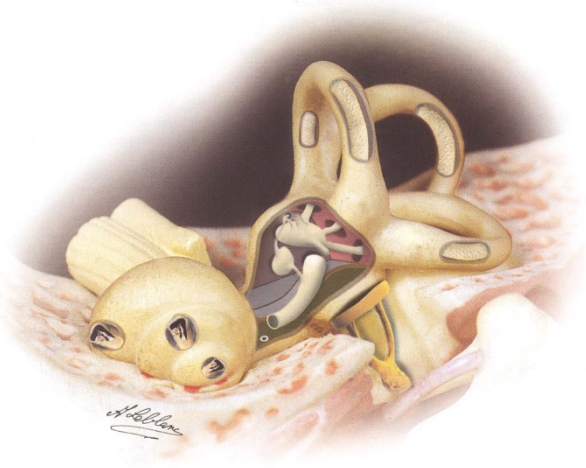
Tests of Peripheral Vestibular Function



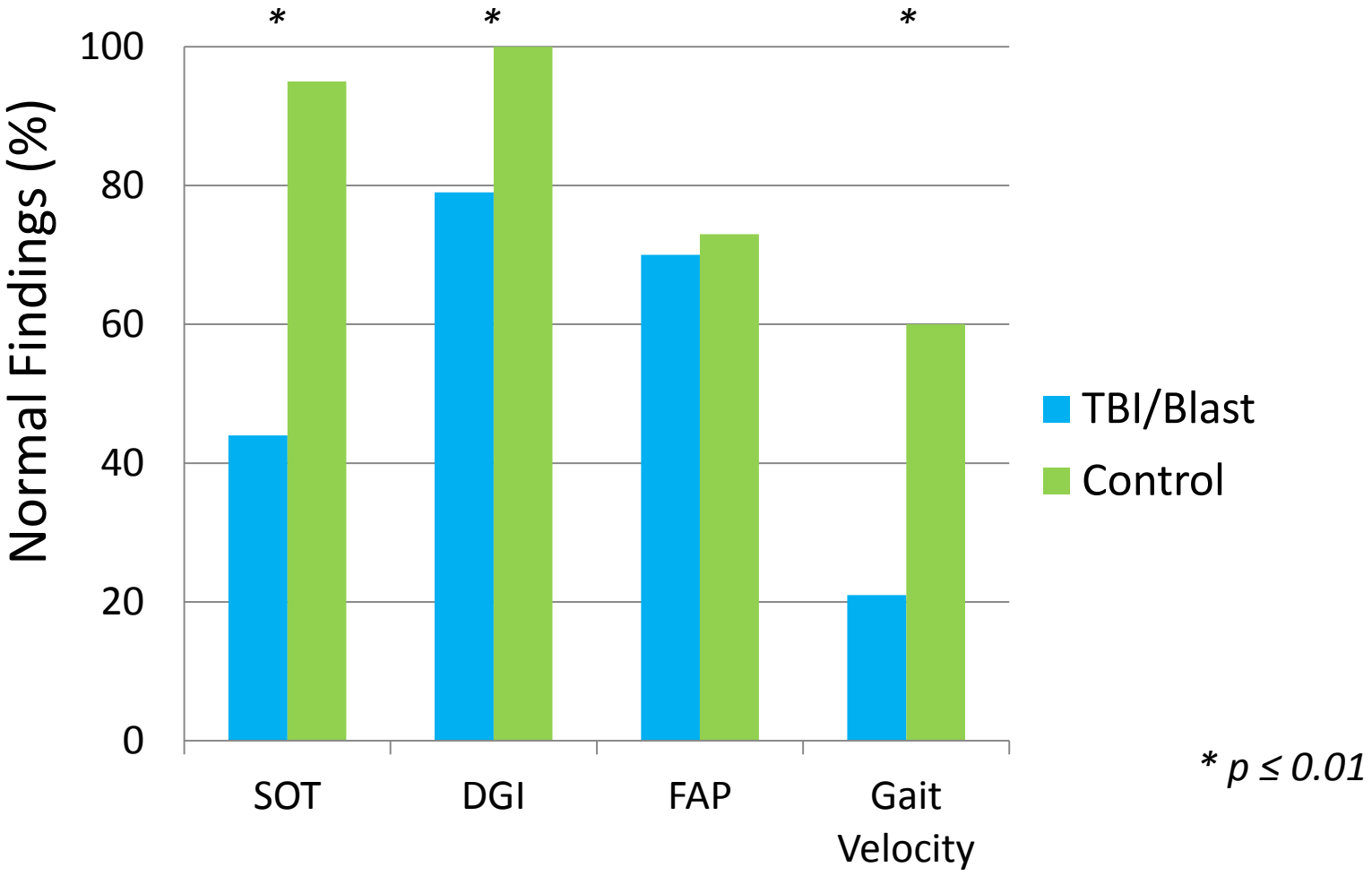
Further evidence

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



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

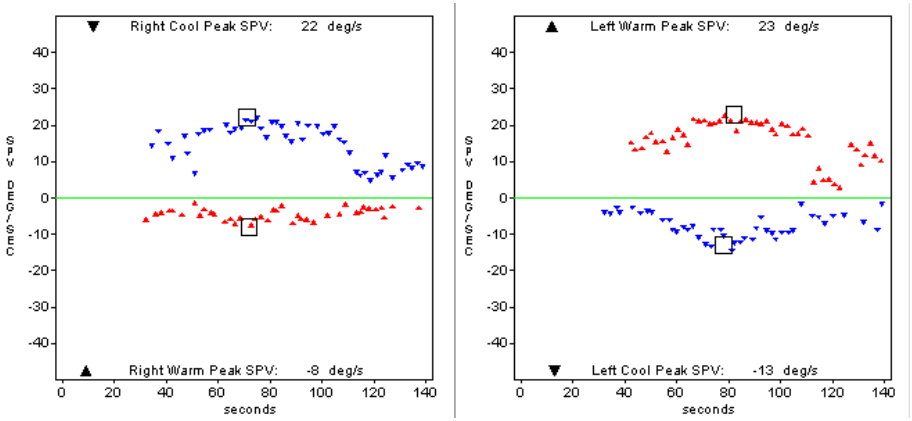
Saccades WNL

Tracking WNL

Normal fixation suppression

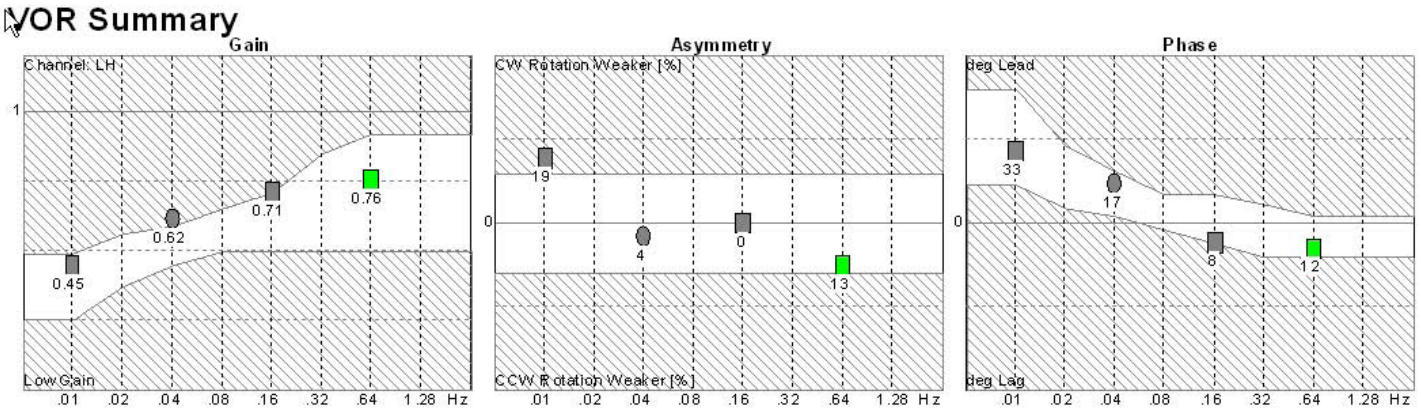
Case Study: hSCC Tests Results

Bithermal Binaural Caloric Test



Caloric nystagmus symmetrical and WNL

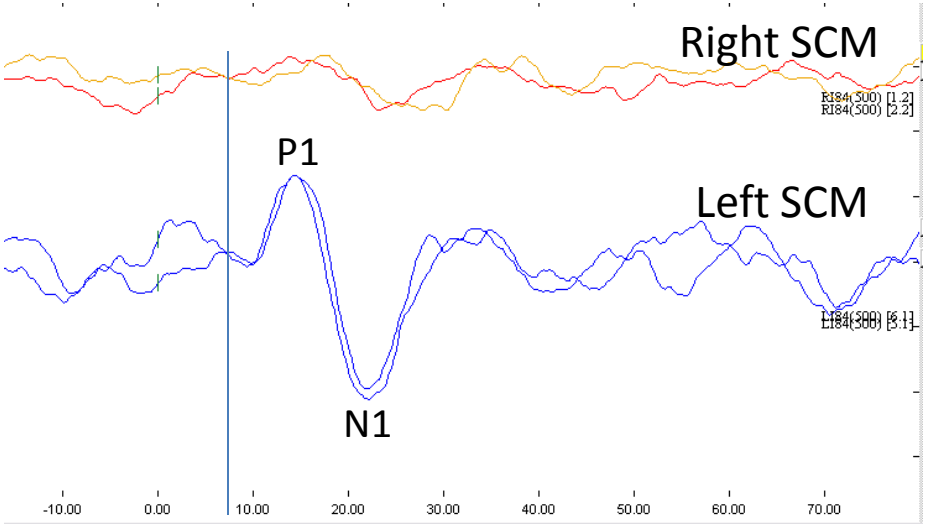
Rotary Chair Test



WNL

Case Study: Otolith Organ Test Results

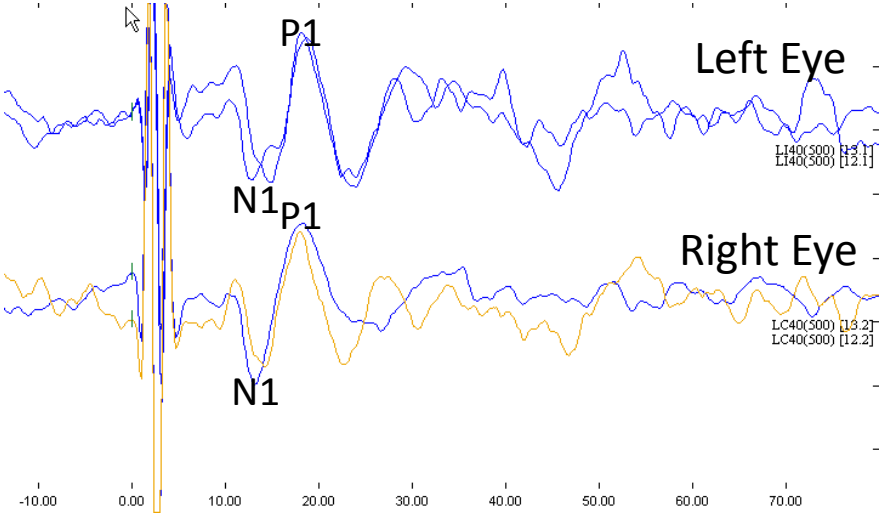
Cervical VEMPs (AC)



Absent cVEMP on the right side

Right saccule/IVN dysfunction

Ocular VEMPs (BC)

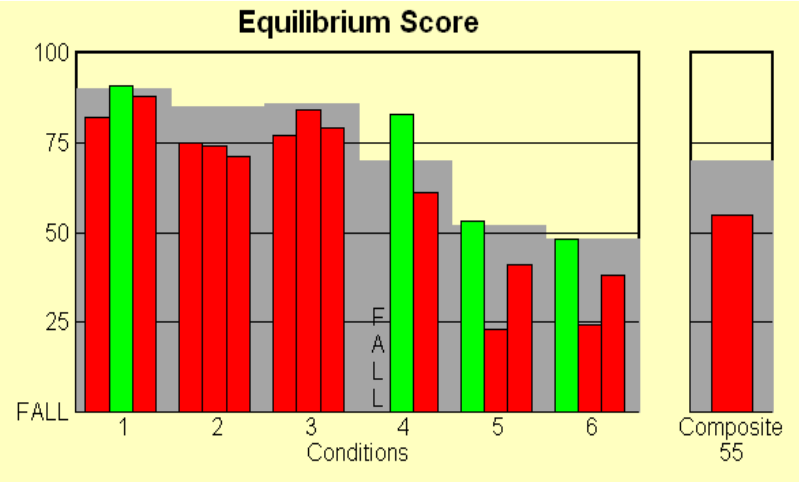


Symmetrical oVEMPs

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)

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