

# Vestibular Symptoms Following mild traumatic brain injury

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Dr. Fife has not financial or other conflicts of interest to disclose

# OUTLINE

- 1. Definitions of Vestibular symptoms, mTBI
- 2. Peripheral vestibular disorders that may follow mTBI
- 3. Vestibular PT and balance retraining PT for dizziness after mTBI
- 4. Mechanisms and effects of mTBI that may lead to CNS related chronic dizziness
- 5. Several potentially treatable CNS phenotypes of chronic dizziness after mTBI
- 6. CNS and Behavioral interactions affecting prognosis and diagnosis of dizziness following mTBI



#### **Definitions by ICVD** Bisdorf et al. J Vestib Res 2009;19:1-13

- Vertigo = sensation of self-motion when no self-motion is occurring and implies internal vertigo (external vertigo is oscillopsia or a visual sense of motion). Examples of vertigo include false spinning, swaying, tilting, bobbing, floating, bouncing, free falling. Vertigo can be spontaneous or triggered.
- Dizziness (non-vertiginous) = the sensation of disturbed spatial orientation without false sense of motion. To be called dizziness it must meet definition but NOT have the illusion of motion, near faintness (presyncope), mental confusion, depersonalization, fatigue or generalized weakness. May be spontaneous or triggered.
  - Dizziness and Vertigo may co-exist in the same patient at the same time. Visually induced vertigo and visually induced dizziness = symptoms induced seeing objects in motion (observing contrasting visual flow)
- Unsteadiness = sensation of sway or poor balance only when standing or walking
- **Vestibular symptoms** = vertigo, dizziness, spatial disorientation and similar symptoms that *may or may NOT* be due to vestibular mechanisms.



by

## **Mild Traumatic Brain Injury**

Defining mTBI, aka concussion, has been a matter of controversy

**WHO**: mTBI with GCS 13-15 and at least one of the following (Lefevre-Dognin et al, Neurochirurgie 2021;67:218-21)

- 1. <30 min LOC
- 2. <24 hours amnesia afterwards
- 3. confusion at the time of the accident
- 4. Transient neurological deficit

**VA:** TBI is mild if structural imaging is normal, <30 min LOC, <24 hours of altered mental state or amnesia, GCS 13-15 (Assistant Secretary of Defense. Traumatic brain injury: Updated definition and reporting. Washington, DC: Department of Defense; 2015.)

Issues still exist with the definition such as whether mild TBI with abnormal structural neuroimaging should be considered the same diagnostic entity as "concussion". (Silverberg & Iverson, Arch PMR 2021;102:76-86)



### What factors predict persistent symptoms after mTBI?

- Premorbid physical problems (medical, cognitive, orthopedic)
- High levels of post-traumatic stress (PTSD) early after injury\*
- Patients with < 11 years of education</li>
- Nausea or vomiting associated with the concussion
- Additional extracranial injuries
- High levels of pain early after injury\*
- Premorbid anxiety, depression or migraine
- Pre-injury somatization tendencies predict chronic symptoms
- Tendencies to catastrophize (assuming that the worst will happen, believing the situation is worse than it is and exaggerating problems to be faced).

*Stulemeijer et al, JPPN 2008; 79:936-42 Hoge et al. NEJM 2008;358:453-63 Nelson et al. Neurology 2016;86:1856-63 Langer et al. PLoS Medicine 2021* 



#### Mild traumatic brain injury (mTBI), or concussion

- Headaches
- Dizziness
- Cognitive inefficiency / reduced concentration
- Depression
- Anxiety
- Fatigue

#### mTBI is he most common type of TBI

Symptoms resolve for half or more within 3 months (Friesen et al PLoS One PLoS One. 2017 Apr 11;12(4):e0174847)

Some have persisting symptoms much longer, even years (Persistent PCS)



## Vertigo Dizziness, Unsteadiness in mTBI

#### PERIPHERAL VESTIBULAR

- Benign Paroxysmal Positional Vertigo (BPPV) and variants
- Labyrinthine Concussion
- Perilymphatic Fistula
- Isolated utricular or saccular sheer injury
- Less common in mild TBI, temporal bone fracture

#### **CNS-RELATED**

•Post-concussive dizziness

- •Post-traumatic vestibular migraine
- •Post-traumatic persistent-postural perceptual dizziness
- •VOR changes (Whitney & Sparto, J Neurol Phys Ther 2019;Suppl 2:S31-S35;

Crampton et al, Neurochirurgie 2021;67:231-7.)

Convergence insufficiency (?) (Barton & Ranalli, Ann Neurol 2020;88:453-461)
Anxiety, depression, somatic symptom disorder

More severe TBI: diffuse axonal injury, hydrocephalus, intracranial hemorrhage, hydrocephalus, contusion, brainstem injury, vertebral artery dissection w/ stroke



# Peripheral Vestibular Disorders after mTBI

- 1. BPPV (most common, about 13%)
- 2. Shearing or tearing of structures of the inner ear
- 3. Labyrinthine concussion
- 4. Injuries of the saccule or utricle can cause tilting
- 5. Unilateral acute vestibular loss (less often in mTBI)
- 6. Post-traumatic Meniere's disease (probably, but rare)
- 7. Others said to be "central" based on exam or testing
  - Reduced VOR suppression by fixation
  - Increased saccade latency
  - Low velocity static positional nystagmus in absence of light
  - Reduced pursuit tracking or optokinetic nystagmus gain



## **The left labyrinth**



## Pathophysiologic Mechanism of BPPV





# Benign paroxysmal positional vertigo (BPPV)

Calcium carbonate debris dislodges from the utricle

The calcium carbonate debris moves in one of the semicircular canals in response to gravity.

The posterior canal is most commonly affected

Vertigo is brief (10-20 seconds) and occurs with turning in bed or tilting one's head back in certain positions.

Dix Hallpike testing will detect characteristic nystagmus.





# Benign paroxysmal positional vertigo (BPPV)

Traumatic BPPV may be more prone to involvement of multiple canals and more recurrences but once cleared is probably not much more likely to recur than in most BPPV patients (Liu 2012, Pérez 2012, Kansu 2010, Aron 2015).

The symptoms usually begin soon (1-3 days) after the concussion.

BPPV is uncommon in those under 18 except with trauma.

Canalith repositioning *procedure* or the Semont maneuver are standard of care treatments (Fife 2008, Bhattacharyya 2008, 2017).



Canalith Repositioning Procedure for Right BPPV



# Shearing, utricular, saccular injury



#### Ocular VEMP tests the utricle

#### Cervical VEMP tests the saccule

VEMP = vestibular myogenic evoked potentials



## **Utriculosaccular dysfunction**

Isolated dysfunction of the otolith organs (utricle and saccule) may occur even when caloric responses are normal (Manzari 2012, Pelosi 2013, Schönfeld 2010)

Vestibular evoked myogenic potentials (VEMP) can detect functioning of the saccule (cervical VEMP) and utricle (ocular VEMP)(Curthoys 2013).



**cVEMP** 

## **Balance Retraining and Vestibular Rehabilitation**

Condition

Response

Acute one-sided vestibular loss Healing of injury Central Adaptation

Labyrinth concussion

n Healing of injury Central Adaptation

**BPPV** 

Mechanical

**CNS** injury

Central Adaptation Plastic changes to brain Functional adaptation Emotional support Rapport, Hope



## **Trauma-Related Dizziness**

**Factors that limit effectiveness of VRT:** 

- Post-traumatic motion sensitivity, visual vertigo
- Depression, anxiety
- Poor carryover poor ability to remember, learn
- Cognitive loss poor ability to understand
- Physical limitations may diminish benefit of PT
- Physical limitations due to fatigue, lack of stamina



# CNS Vestibular symptoms / Dizziness after mTBI



# **Microstructural CNS injury from TBI**

- How to determine who has WM microstructural injury to axons, myelin disruptions, altered neurochemistry and cerebral autoregulation (Przekwas 2016) and who does not.
- Diffusion tensor imaging (DTI) and neurite orientation dispersion and density imaging (NODDI) are being studied (Palacios et al, Sci Adv 2020; 6(32):eaaz6892)

Adapted from Donovan et al. J Cereb Blood Flow Metab 2014;34(4):715-23



# **Microstructural CNS injury from TBI**

Cannot see these changes by brain MRI, current functional imaging. Diffusion tensor imaging and other techniques promising but not ready for prime time.

Clinical exam does not distinguish one group from the other.

Cannot use the duration or severity of symptoms

Cannot reliably look at the nature of the head blow (when knowable).

Anxiety and neurobehavioral effects may be the result of such microstructural injury or may have predated the injury thus manifesting without direct effect from the trauma.



### Blast Wave Effects on the Skull and Brain



Gupta and Przekwas, Front Neurol 30 May 2013

- Deformation of skull
- Deformation of brain with shear/compression\*
- Direct blast wave entry via orbit, ear, etc.
- Elastic wave via blood vessels from thoracic compression
- Wave passes through brain faster than through air.
- Further injury from post wave recoil of head



Dizziness "Phenotypes" after mTBI that can possibly respond to treatment



## Persistent Postural-Perceptual Dizziness (PPPD)

- A. One or more symptoms of dizziness, unsteadiness, or non-spinning vertigo are present on most days for ≥3 months lasting hours
- B. Persistent symptoms are not provoked by anything specific but worsened by being upright, exposure to moving visual stimuli or complex visual patterns
- C. The disorder may be precipitated by conditions that cause vertigo, unsteadiness, dizziness, imbalance due to vestibular or other medical issues, stress, anxiety, depression and may worsen over time.
- D. Symptoms cause significant distress or functional impairment (*out of proportion to physical limitations seen on examination*).
- E. Symptoms are not better accounted for by another disease or disorder.

(Staab et al. J Vestib Res 2017;27:191-208)



## Posttraumatic Vestibular Migraine and migraine phenotype headaches

Posttraumatic migraine-like headaches, and to a lesser degree dizziness, are common after minor trauma to the head and neck (Margulies 2000, Donaldson 2010).

Patients with migrainous vertigo following mTBI may have spinning, rocking, to-and-fro sensations or floating very commonly with nausea

Persisting nausea and motion sensitivity and visually-induced dizziness for weeks and months after mTBI with no evident primary inner-ear cause. This is a vestibular migraine or persistent postural-perceptual dizziness phenotype.



## **Treatment for vestibular migraine**

#### Drug Class

Verapamil Tricyclics

SNRIs

Antiepileptic

Antiepileptic Beta blockers GGRP Binding Ab (?? for dizziness)

Clonazepam\*

#### Example, Dose Range

Verapamil 120-360 mg qd

Nortriptyline 25-100 mg qd Imipramine 25-75 mg qd Amitriptyline 25-50 mg qhs Venlafaxine 25-150 mg qd Duloxetine 30-90 mg qd Topiramate 25-200 mg qd

Valproate 125-500 mg bid Propranolol 80-180 mg qd Gacanezumab, erenumab, fremanezumab

.25 -1 mg bid regularly, prn

#### Adverse effects

Constipation, GERD

Weight gain, dry mouth, sedation, perspiration

Insomnia, nausea, perspiration

Cognitive SFx, sedation, dysgeusia

Wt gain, hair loss, tremor

Fatigue, low BP/HR

Possible constipation

Sedation; dependency



# CNS and Behavioral Causes of Persisting Dizziness



## **Difficult Issues in mTBI / persistent PCS**

- mTBI / pPCS symptoms also occur in those without head trauma (anxiety, migraine, PPPD, Havana syndrome)
- Conflation, over-attentiveness to symptoms so that all are attributed to mTBI including everyday aches and pains. Sometimes chart notes add confusion.
- MRI-visible and more commonly microstructural CNS injury may occur after concussion but we lack reliable imaging biomarkers (e.g., anisotropy with DTI etc.)
- Probably not every blow to the head causes microstructural injury
- Powerful interplay between proneness for anxiety, PTSD, depression, victimhood mentality, catastrophizing, assuming the "sick role", desire for attention, excuse for non-success, litigation, other financial gain
- In some of these patients, it seems trauma may induce a vestibular migraine-like process of dizziness



## CNS, Psychological, Behavioral & Psychosocial Milieu and Persisting Dizziness

What may have started as just vestibular symptoms later becomes entwined with:

- disabling anxiety
- migrainous vertigo symptoms (especially if untreated)
- ongoing litigation
- altered self-identity or self-worth
- elements of PTSD
- stress related to obtaining and keeping disability coverage
- financial fears
- fatigue and time consumed by healthcare visits and treatments
- differing opinions by various care professionals
- personal issues such as divorce, loss of house, etc.



## CONCLUSIONS

- 1. The dizziness or imbalance can result from trauma to the inner ear, nerve, or CNS or all of the above.
- 2. BPPV is a common and easily treated consequence of traumatic head injury.
- 3. Dizziness from permanent injury to the inner ear and to a lesser extent to the brain itself can improve via CNS plastic adaptations
- 4. Vestibular and balance training may help improve symptoms significantly in dizzy or ataxic TBI patients but is most helpful when there is documented vestibular loss or BPPV.
- 5. Determining the factors at play in an individual is a case by case analysis
- 6. Treatment of certain dizziness "phenotypes" may be worth trying when they apply.

