CONCUSSION & POST-TRAUMATIC VESTIBULOPATHY: A CASE STUDY

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Chatham University Physical Therapy

Grand Rounds

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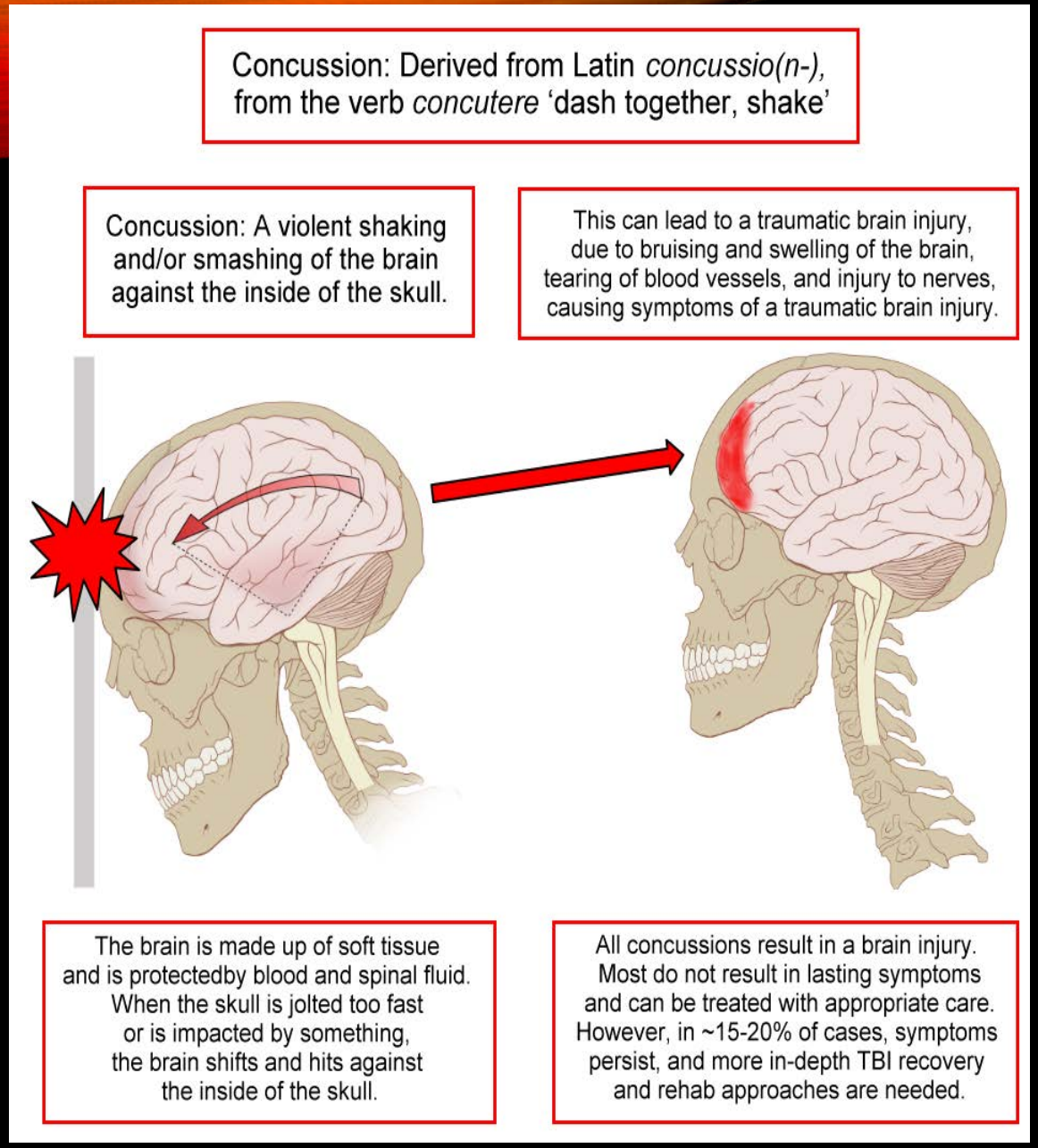
LEARNING OBJECTIVES:

- 1. To understand the pathophysiology of concussion and vestibular dysfunction associated with concussion.
- 2. To understand the pathophysiology of peripheral vestibulopathy.
- 3. To identify key elements in the physical therapy examination of concussion and vestibulopathy.
- 4. To identify key physical therapy treatments for concussion and vestibulopathy.
- 5. To identify differential diagnosis in central vs. peripheral vestibular disorders
- 6. To understand how and when to make appropriate referrals in the management of a complex vestibular patient.

WHAT CAUSES CONCUSSION?



- A "Concussion" is a mild traumatic brain injury
- The word concussion is derived from Latin and literally means "to shake violently."
- Example: Think of the human brain as an egg yolk, and skull as an egg shell
- When a person's head or body takes a hit, it can cause the brain to shake around inside of the skull, causing injury to the brain
- A concussion may also be caused by impact to the body, causing a whiplash effect on the brain.
- *www.rethinkconcussions.upmc.com*

ANATOMY OF CONCUSSION

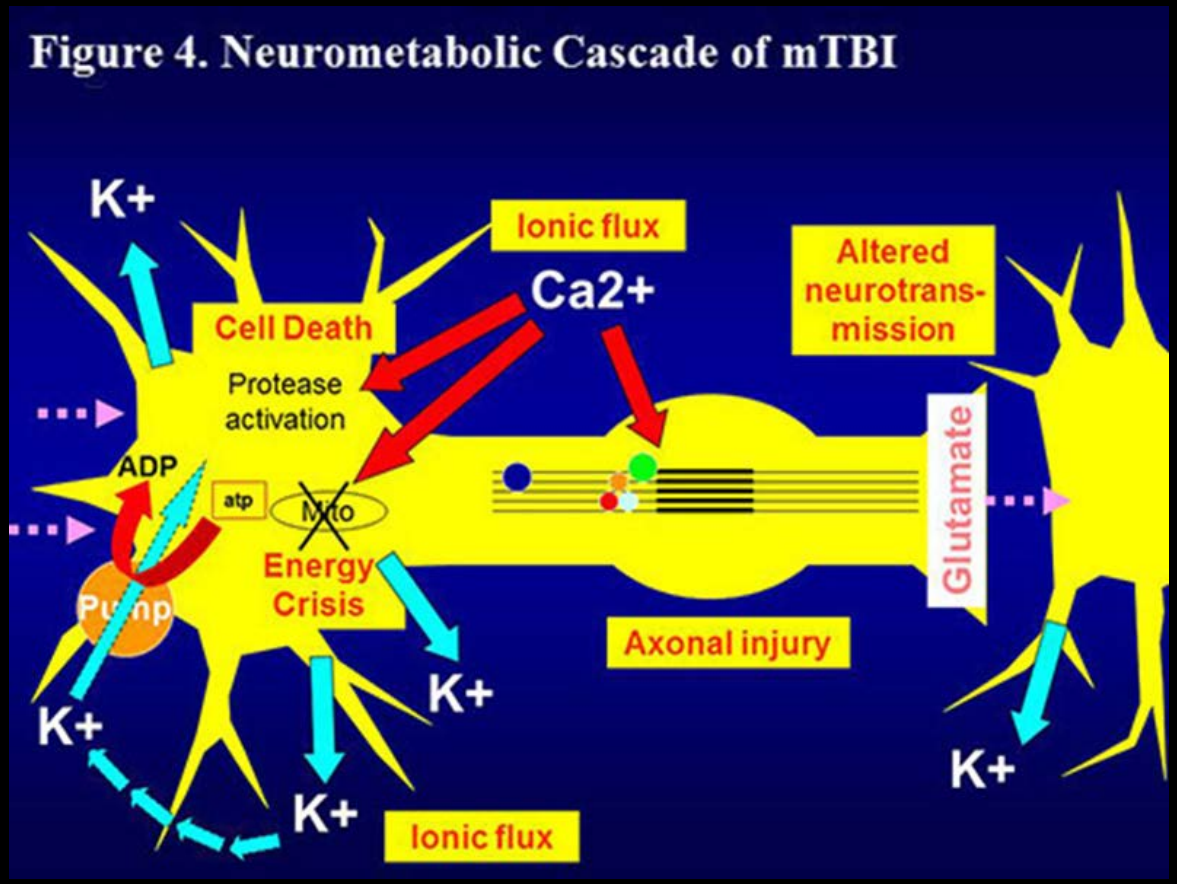
A sudden acceleration-deceleration injury leads to axonal shearing or swelling

Shearing/swelling then leads to a neuro-metabolic change at the cellular level of the neuron

Causes Potassium Ions (K+) to rush OUT of the cell & Calcium Ions (Ca2+) to rush INTO the cell = increased need for GLUCOSE

Influx of Calcium = TOXIC, causing vasoconstriction & ↓ blood flow

"ENERGY CRISIS" in brain because brain needs ↑ Glucose to heal…



Pathophysiology of Sports-Related Concussion An Update on Basic Science and Translational Research Christopher C. Giza, MD*† and John P. DiFiori, MD

Concussion Symptoms & Common Clinical Trajectories:

*Cognitive Fatigue

*Vestibular

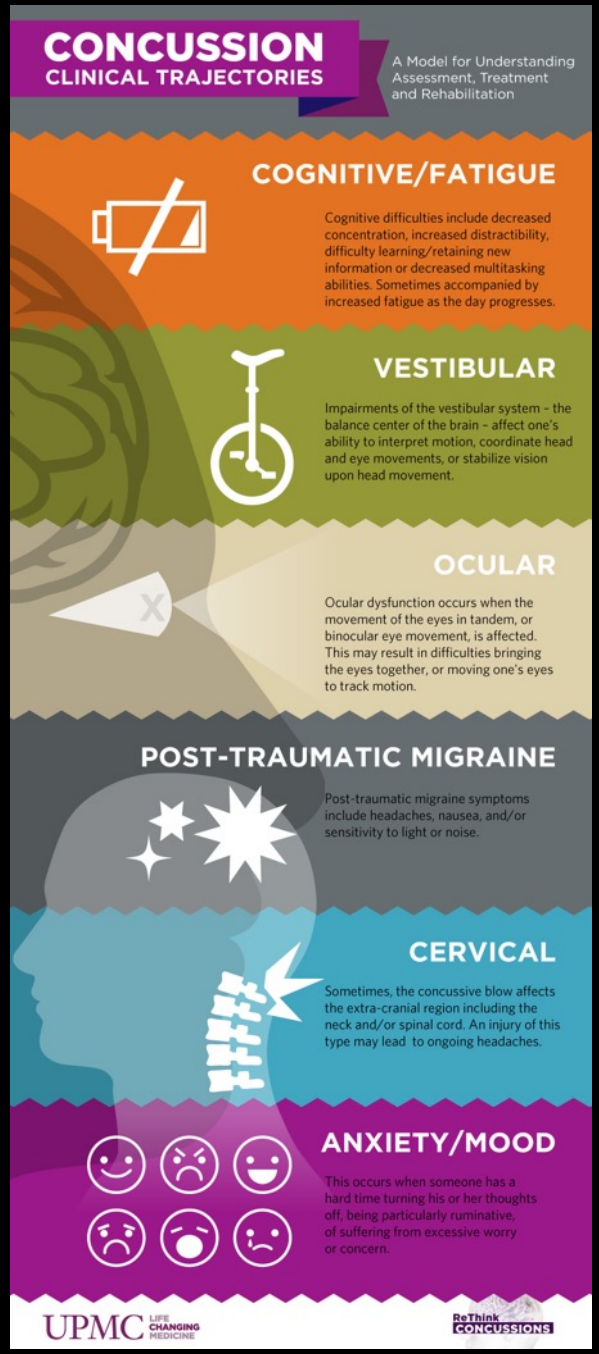
*Ocular

*Post-Traumatic Migraine

*Cervical

*Anxiety/Mood

www.rethinkconcussions.upmc.com



MOST COMMON SYMPTOMS AFTER CONCUSSION: 1-7 DAYS POST-INJURY

KONTOS, ET AL., 2013, AM J SPORTS MED

#1	**Headache**	**75%**
#2	Difficulty Concentrating	57%
#3	Fatigue	52%
#4	Drowsiness	51%
#5	Dizziness	49%
#6	Foggy	47%
#7	Feeling Slowed Down	46%
#8	Light Sensitivity	45%
#9	Balance Problems	39%
#10	Difficulty with Memory	38%

VESTIBULAR CAUSES OF DIZZINESS AFTER CONCUSSION:

- PERIPHERAL:
  - BPPV
  - Labyrinthine Concussion
  - Perilymphatic Fistula
  - Post-Traumatic Vestibulopathy

- CENTRAL:
  - *Post-Traumatic Migraine
  - *Brainstem Concussion

- NON-VESTIBULAR CAUSES OF DIZZINESS:
  - Oculomotor Problems
  - Autonomic Dysfunction (Orthostasis)
  - Cervicogenic Dizziness

- *Adapted from Furman, 2010*

PERIPHERAL SYMPTOMS OF VESTIBULAR DYSFUNCTION AFTER CONCUSSION:

Trauma can cause any of the following symptoms:

*Dizziness

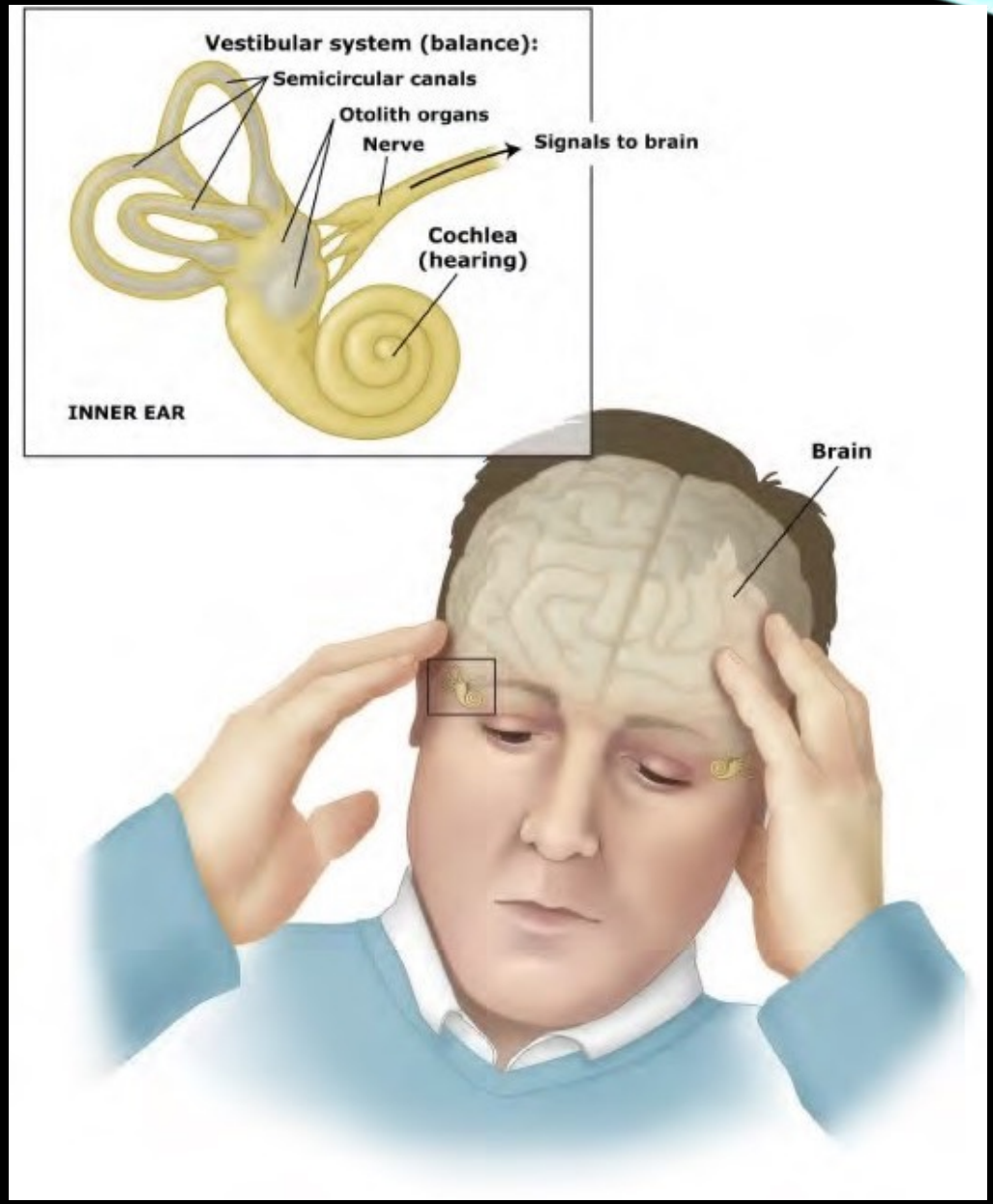
*Vertigo (spinning sensation)

*Nausea &/or vomiting

*Imbalance or Falls

*Hearing Loss or Tinnitus

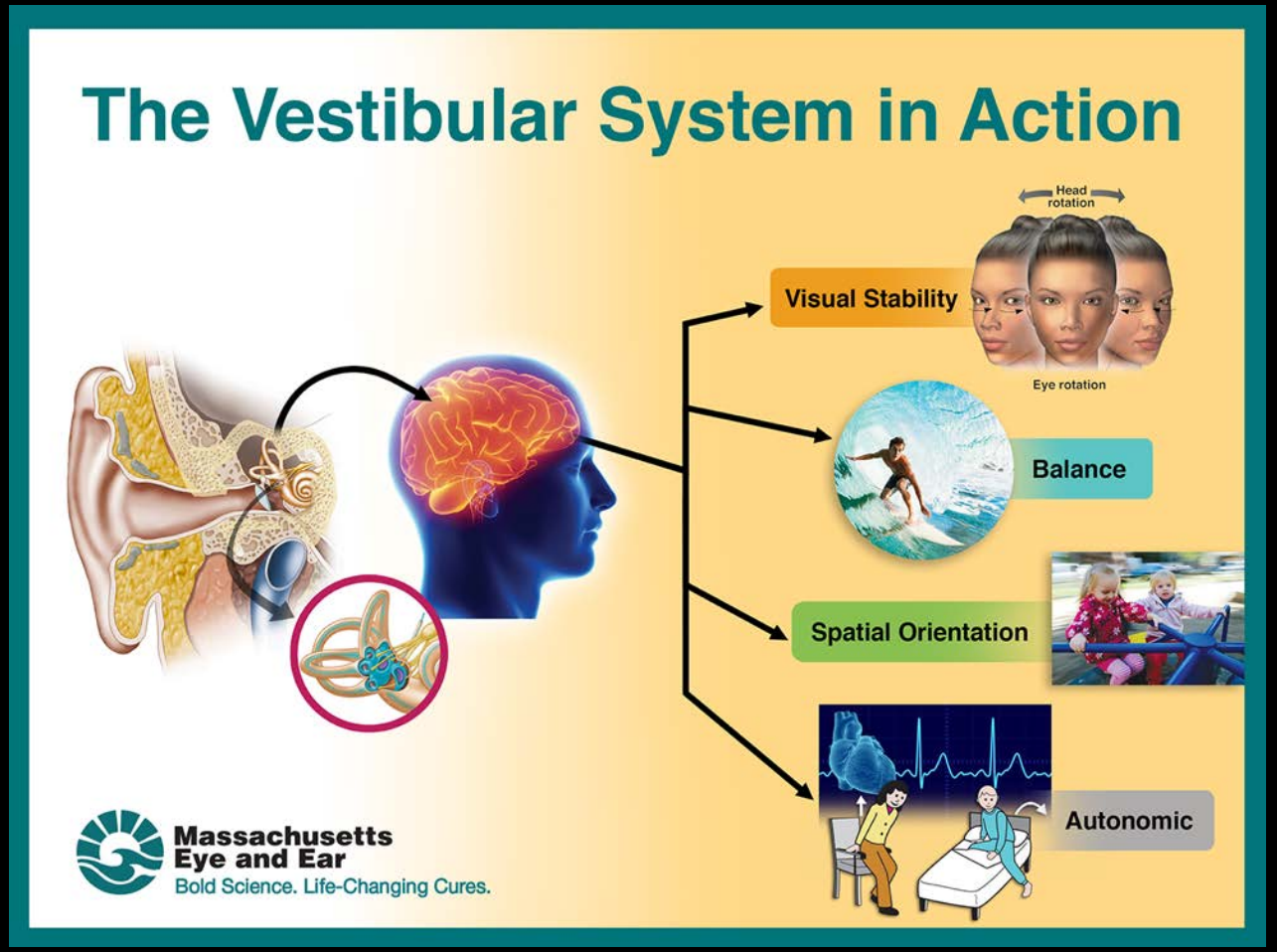
*Blurry vision



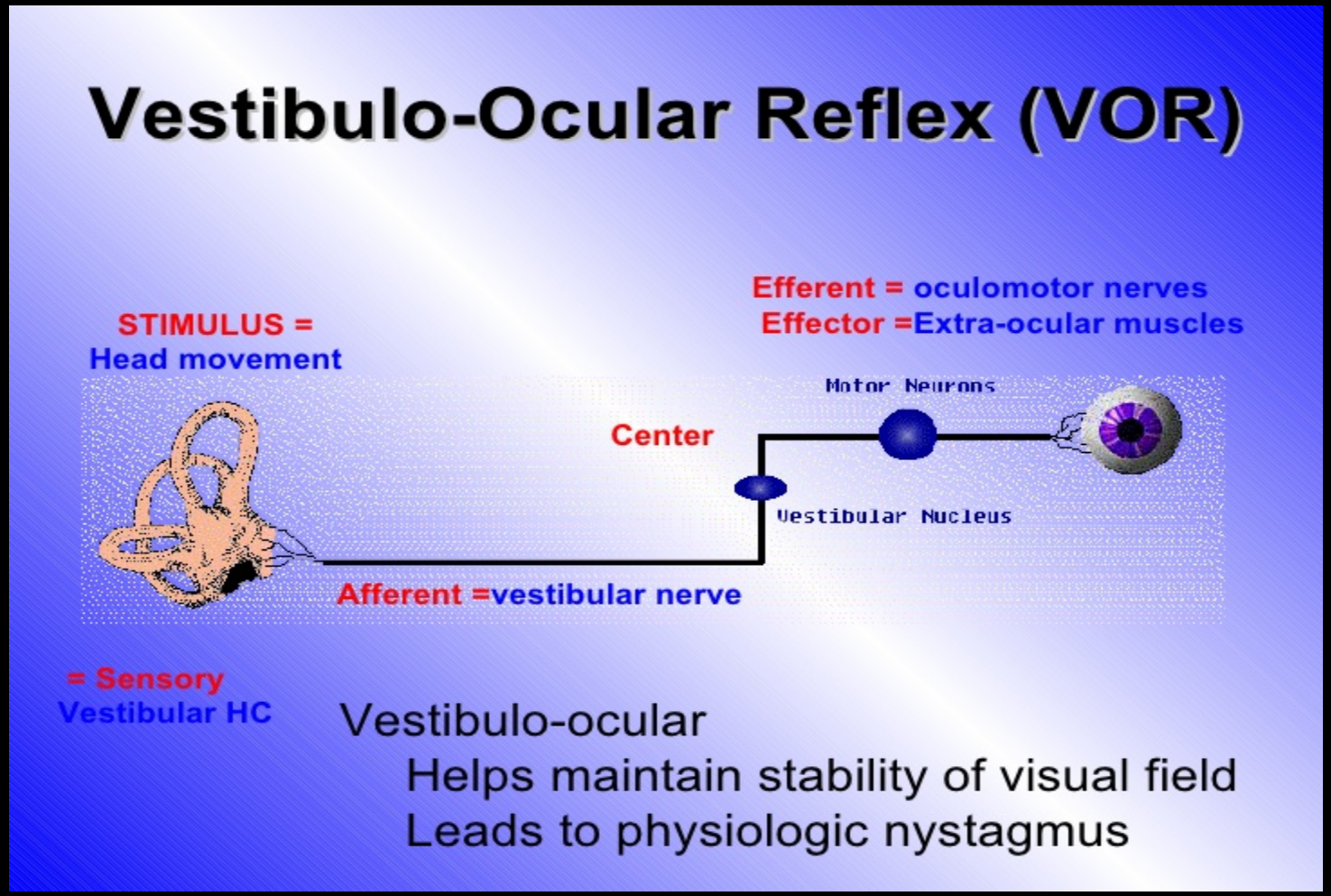
www.emedmd.com/vertigo-and-imbalance

FUNCTIONS OF PERIPHERAL VESTIBULAR SYSTEM

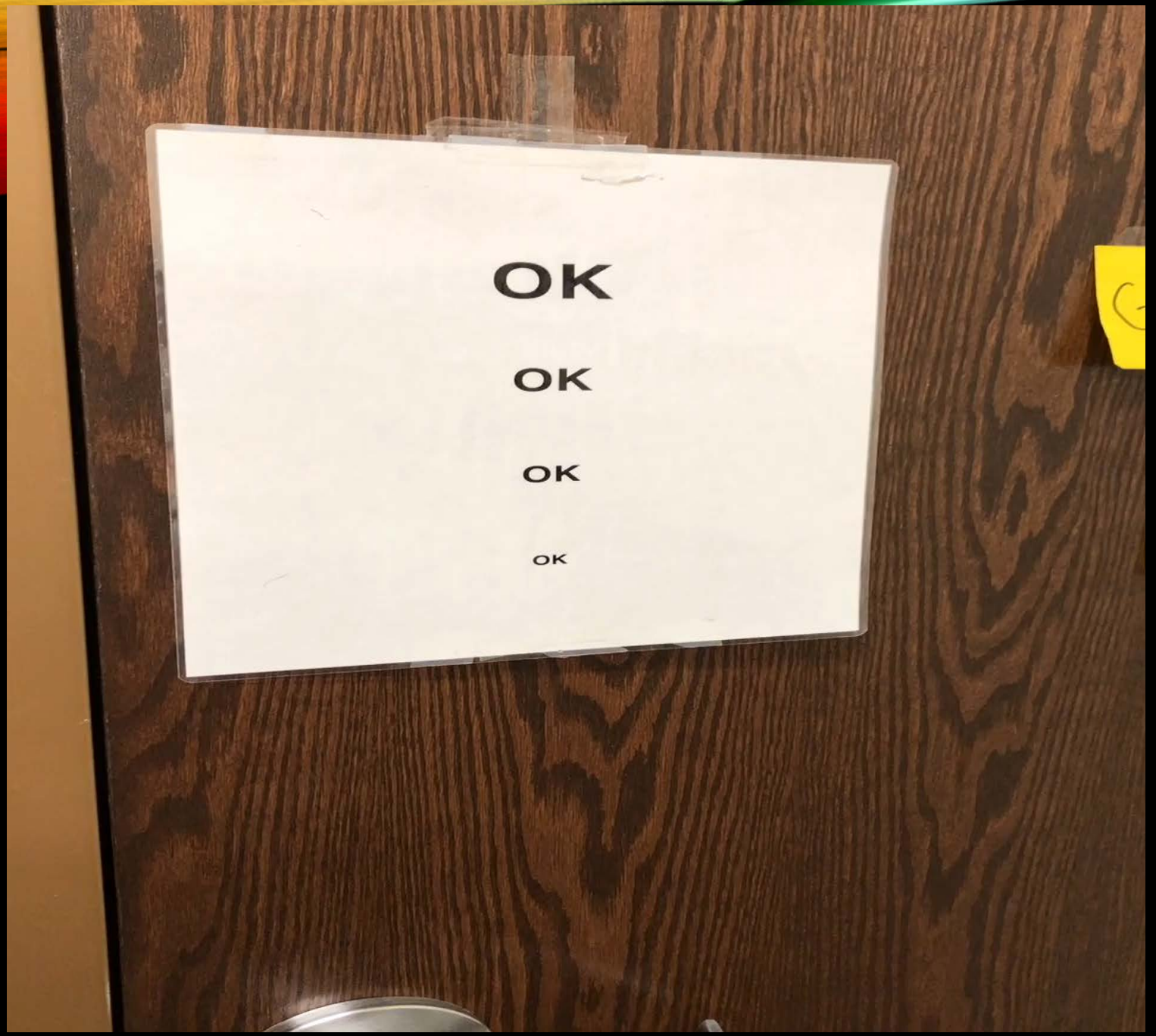
- 3 PRIMARY FUNCTIONS:
  - 1. Stabilizing visual images on the fovea of retina during head movement to allow clear vision (VOR x 1)
  - 2. Maintaining postural stability, especially during head movement
  - 3. Providing information used for spatial orientation



PHYSIOLOGY & MOTOR CONTROL OF VOR FUNCTION:



The Central Vestibular pathways that control VOR function are based upon a 3-Neuron Arc:



VOR X 1

CENTRAL SYMPTOMS OF VESTIBULAR DYSFUNCTION AFTER CONCUSSION:

*Headaches

*Blurry Vision

*Double Vision

*Difficulty Concentrating

*Difficulty with Memory

*Fogginess

*Dizziness

*Imbalance

CENTRAL VS. PERIPHERAL SIGNS OF VESTIBULAR DYSFUNCTION:

PERIPHERAL

- Direction-fixed nystagmus (Horiz.)
- Nystagmus ↑ with fixation removed
- Nystagmus ↑ with gazing in direction of the fast component (Alexander's Law)
- Nystagmus ↑ after head shake test
- Pursuits & Saccades Normal
- Able to stand & walk with assistance
- Abnormal VOR function

CENTRAL

- Direction-changing nystagmus
- Nystagmus ↑ with fixation
- Nystagmus more likely pure vertical or pure torsional
- Nystagmus post-head shake is more vertical
- Likely abnormal pursuits & saccades
- Unable to stand & walk most likely
- *O'Sullivan & Schmitz, 6th edition*

CENTRAL VS. PERIPHERAL SYMPTOMS OF VESTIBULAR DYSFUNCTION:

PERIPHERAL:

- Nausea/vomiting severe at onset
- Imbalance mild
- Hearing loss common
- Neurologic symptoms rare
- Compensation occurs rapidly

CENTRAL:

- N/V moderate at onset
- Imbalance severe
- Hearing loss rare
- Neurologic symptoms common
- Compensation occurs slowly
- *O'Sullivan & Schmitz,* 6th edition

CLINICAL VS. DIAGNOSTIC TESTING AFTER CONCUSSION:

CLINICAL:

- Abnormal VOMS following Concussion: (% reporting symptoms)
- Smooth pursuits- 33%
- Horizontal Saccades- 42%
- Vertical Saccades- 33%
- Horizontal VOR- 61%
- VMS- 49%
- Convergence- 34%
- *(Mucha, Collins, et al., 2014)*

DIAGNOSTIC:

Vestibular Function Tests (% abnormal)

- 63% caloric and 47% rotational chair tests *(Toglia, 1970)*
- 74% abnormal vestibular tests *(Davies & Luxon, 1995)*
- 57% reduced dynamic visual acuity *(Zhou et al., 2015)*
- mTBI may cause post-traumatic vestibulopathy of mixed central & peripheral origin *(Alhilali et al., 2014)*

HOW TO ASSESS VESTIBULAR DYSFUNCTION AFTER CONCUSSION:

- VOMS: "Vestibular/Ocular-Motor Screening for Concussion"
  - Designed for use with subjects ages 9-40. When used with patients outside this age range, interpretation may vary. Abnormal findings or provocation of symptoms with any test may indicate dysfunction- and should trigger a referral to the appropriate health care professional for more detailed assessment and management.

  - Equipment: Tape measure (cm); Metronome; Target with 14 point font print
  - Items this tool measures:
    - Baseline symptoms recorded
    - Smooth Pursuits
    - Saccades (H/V)
    - Convergence
    - VOR x 1 (H/V)
    - VMS (Visual motion sensitivity)

VOMS- VESTIBULAR /OCULAR-MOTOR SCREENING FOR CONCUSSION:

WHAT ELSE NEEDS TO BE TESTED AFTER A CONCUSSION ?

- Cover/Uncover Testing and Cross Cover Testing for Ocular Misalignments (tested with a Maddox Rod & pen light)
- Gaze Testing in Daylight, then with Fixation blocked testing (goggles)
- Position testing to rule out BPPV: Dix Hallpike & Roll testing (goggles)
- Modified Clinical Test of Sensory Integration & Balance (mCTSIB)
- 4 item Dynamic Gait Index (DGI)
- Clinical Dynamic Visual Acuity (cDVA)- with LogMAR eye chart
- Head Shake Nystagmus Test
- Head Impulse (Thrust) Test

ARE VOR & POST-CONCUSSION IMPAIRMENTS DUE TO PERIPHERAL OR CENTRAL INJURY?

- ***Concussion likely impairs the CENTRAL structures of the Vestibular-Ocular and Oculomotor Systems…***

- **BUT…what happens when your patient presents with both CENTRAL & PERIPHERAL SIGNS OF VESTIBULAR DYSFUNCTION???**

"KAT" A CASE STUDY:

- Kat is a 19 year old female referred to Vestibular PT s/p concussion 9 days prior to her first Vestibular PT appointment
- PMH: Cerebral Palsy, GERD, 1 prior concussion 1 year ago due to fall with complete recovery within 2 months
- HPI: Kat sustained a concussion after hitting the LEFT side of her head accidentally on a car door…initial complaints were headache & dizziness, photo/phonosensitivity, NO nausea or vomiting, no gait imbalance.
- 3 days after her initial injury, while at work as a summer camp counselor, Kat developed **SUDDEN, SEVERE** onset of dizziness, spinning sensation, nausea and vomiting (>10x) and only able to walk with a wheeled walker (normally walks with bilateral lofstrand crutches.)

"KAT" A CASE STUDY:

- ER visit: Head CT normal, Labs normal, but the Medical student noted:
- "**HINTs exam:"** Left fast gaze unilateral horizontal nystagmus, worse w/ lateral gaze to the left, better with lateral gaze to the right. LEFT sided positive head impulse test. Negative test of skew…
- ***HINTs Exam***="Head Impulse, Nystagmus, Test of Skew"
- ER treatment: Kat spent the day in hospital on observation and received IV fluids, IV Zofran and Meclizine under observation for symptom management.
- D/C diagnosis from ER: "Post-concussive syndrome, Intractable Vertigo"
- Referral to "UPMC Concussion Clinic"

"KAT" A CASE STUDY:

- Concussion Clinic appointment 8 days after initial injury
- CC: HA 4/10, dizziness, imbalance (worse than normal with CP,) fatigue, difficulty concentrating, blurry vision, hypersomnia
- VOMS score= 59 (Normal= 0)
- ImPACT Test Results: neurocognitive impairment in verbal memory (53%), visual memory (9%), visual motor speed (18%) and reaction time (1%)…Kat's baseline scores ~ 85th%
- **Vestibular/Ocular Motor Screening**: Vestibular screening was minimally provocative for dizziness. Convergence was within normal limits. Nystagmus was observed throughout evaluation
- Patient referred to Vestibular PT

"KAT" A CASE STUDY:

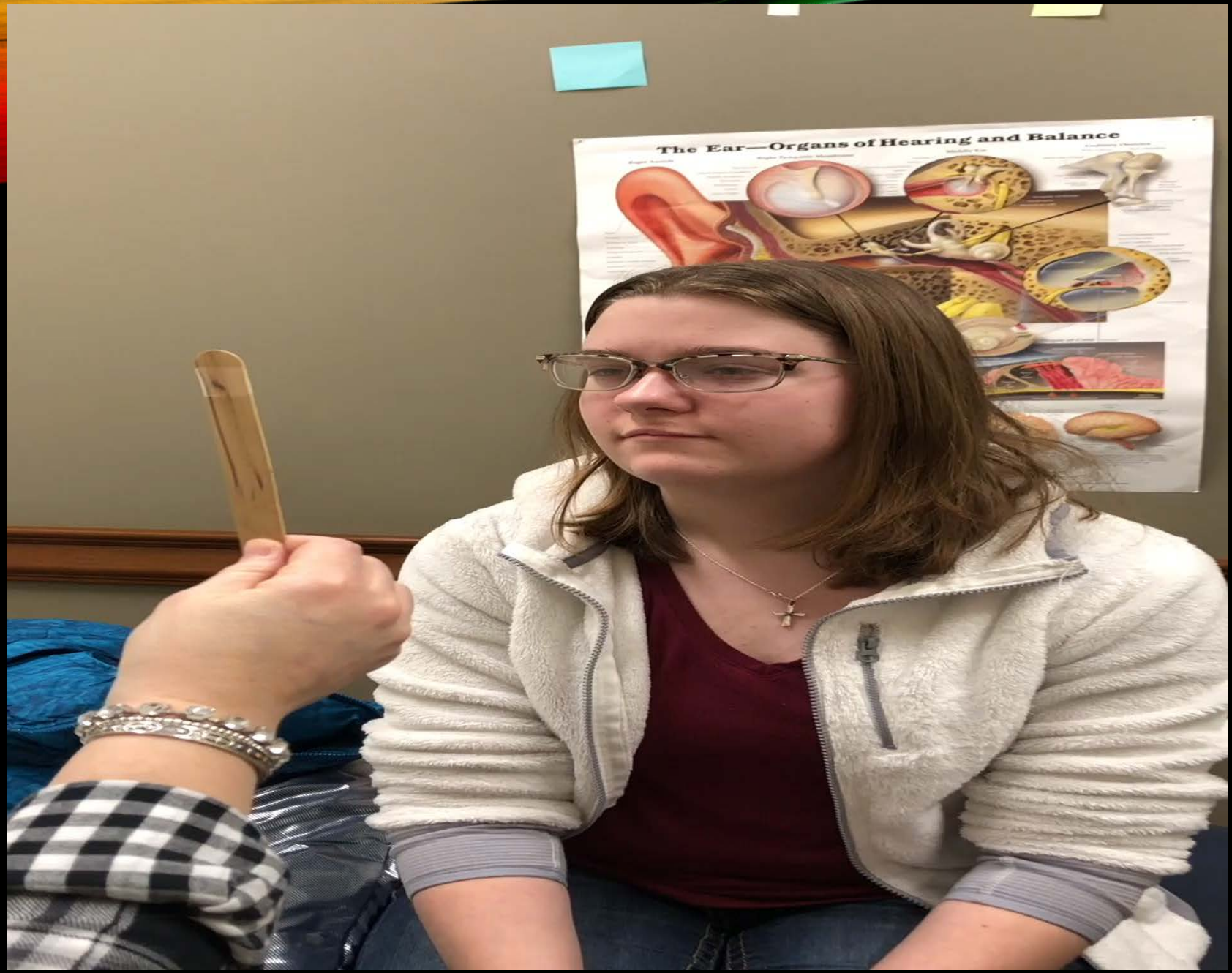
- Initial Vestibular PT assessment: 9 days following concussion

- VOMS= remains grossly abnormal, symptom score 65
- Smooth pursuits- abnormal with saccadic intrusions/nystagmus
- Saccades- abnormal with nystagmus
- NPC= 6cm
- VOR x 1- abnormal with retinal slips noted, Horizontal > Vertical
- VMS- abnormal with saccadic intrusions, Horizontal & Vertical
- All testing increases her dizziness & nausea
- mCTSIB abnormal with posterior LOB during EC Firm, and EO/EC on Foam

"KAT" A CASE STUDY:

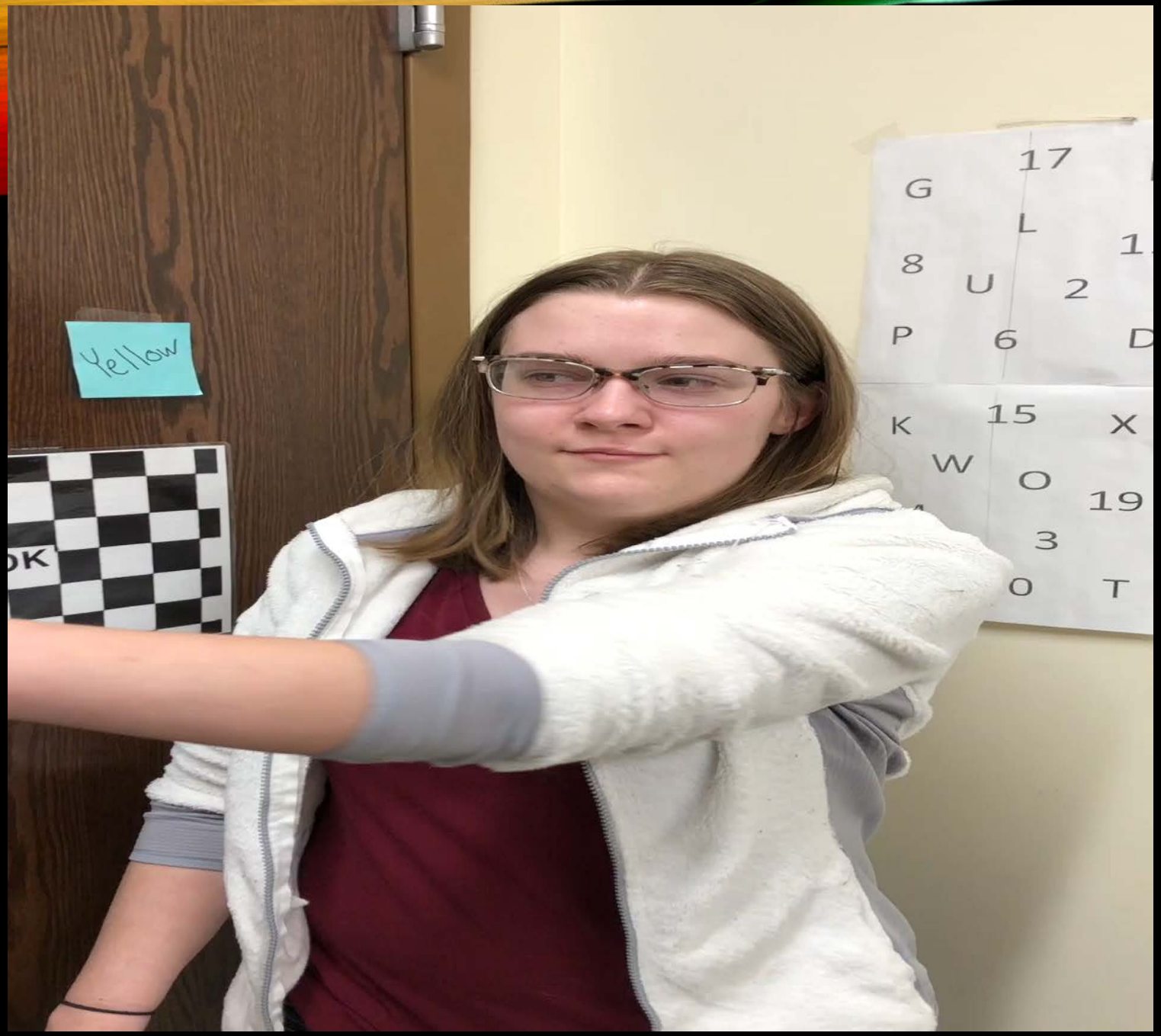
- Gait assessment: CP-like scissoring gait noted, patient unable to ambulate with her lofstrand crutches, now using a wheeled walker with supervision
- Gaze testing in Daylight: ***observed spontaneous LBN in forward gaze, increases with gaze to left, and LBN also present with gaze to right, but less***
- Fixation blocked gaze testing (goggles): same presentation as above, but greater velocity of nystagmus noted
- Dix Hallpike & Roll Testing: no torsional nystagmus noted, no worsening of dizziness reported, observed the ***same LBN regardless of test position***

- Head Thrust Test: Positive RIGHT with corrective saccade noted, Normal LEFT

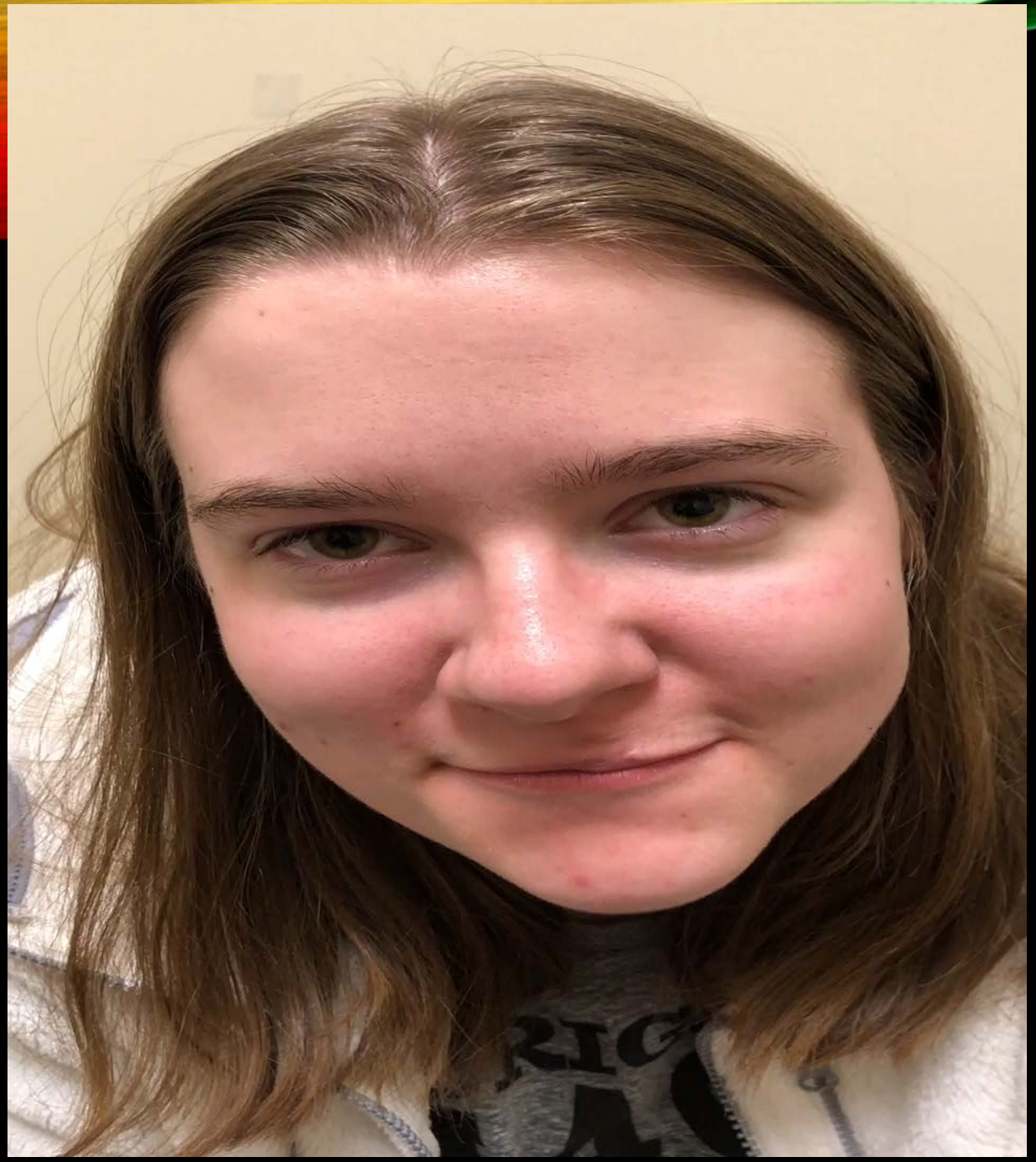


"KAT" A CASE STUDY: VIDEO-SMOOTH PURSUITS

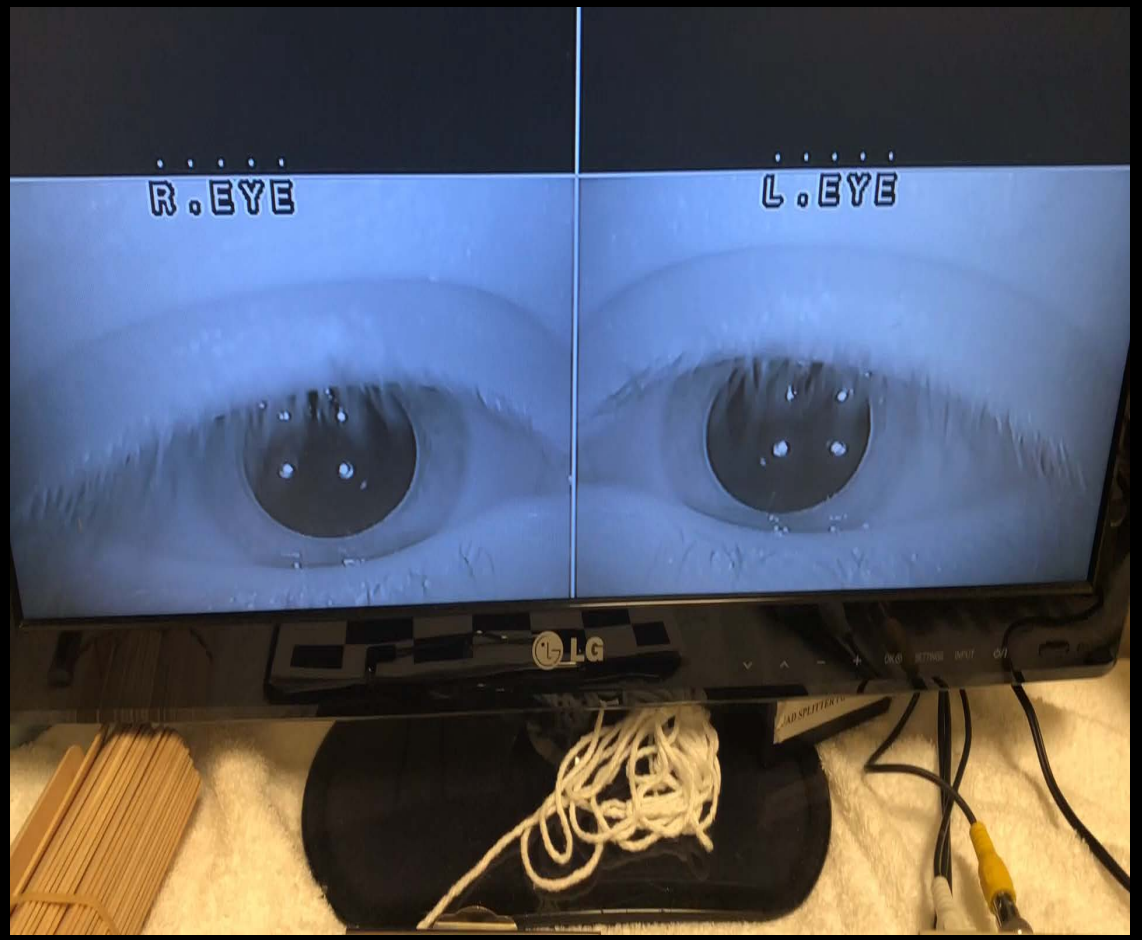
"KAT" A CASE STUDY: VIDEO-SACCADES



"KAT" A CASE STUDY: VIDEO- VISUAL MOTION SENSITIVITY



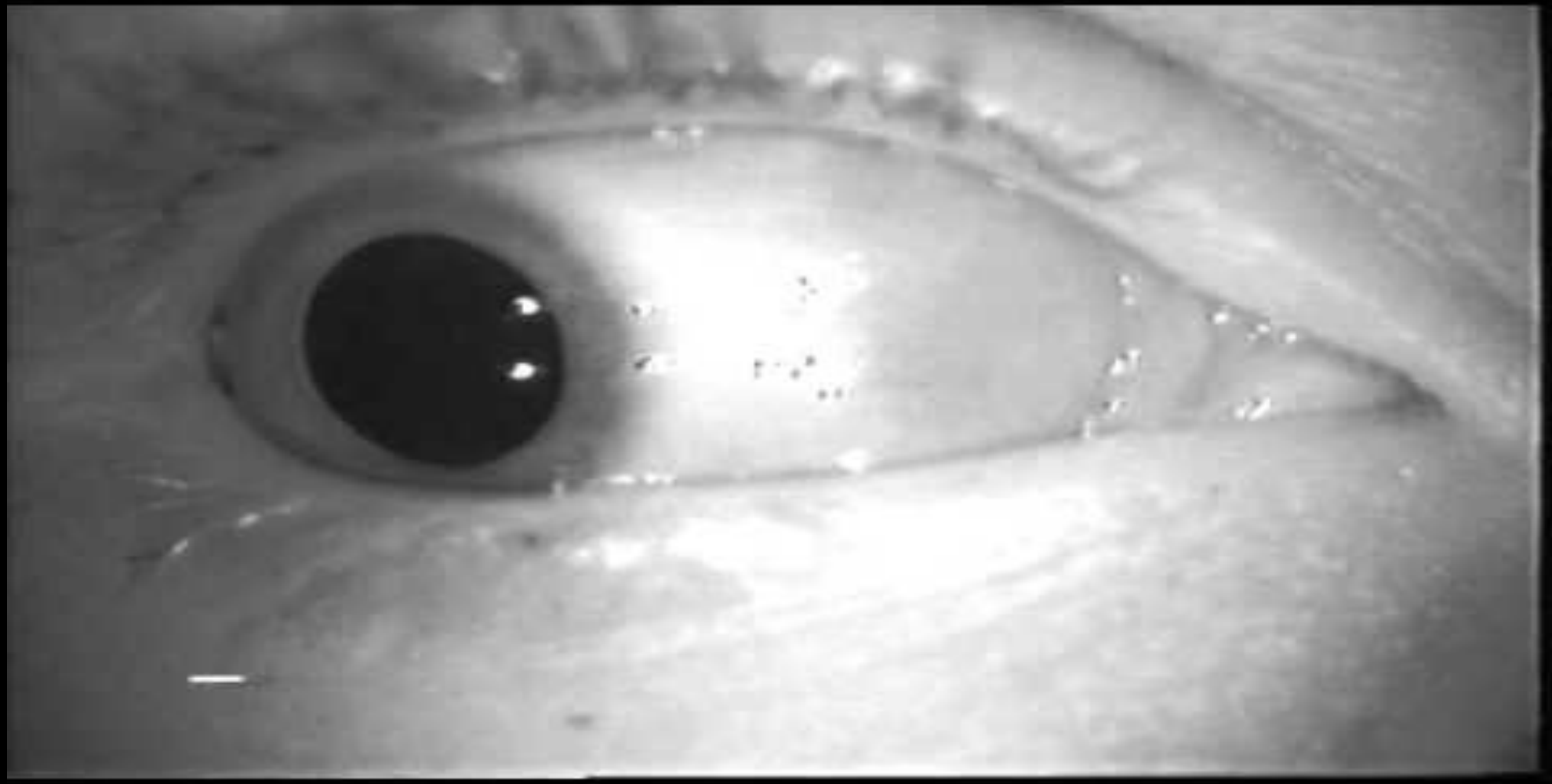
“KAT” A CASE STUDY: VIDEO- GAZE TESTING



ALEXANDER'S LAW:

- **Alexander's Law-** refers to the type of spontaneous nystagmus that occurs after an acute unilateral vestibular loss
- **Alexander's law** states that in individuals with nystagmus, the amplitude of the nystagmus increases when the eye moves in the direction of the healthy ear. (The fast phase of the nystagmus is toward the healthy ear)
- The nystagmus may slow down in central gaze, but **remains direction fixed**.
- The nystagmus may be absent when patient gazes in direction of the lesion or the "unhealthy ear"
- The law was named after Gustav Alexander who described it in 1912.
- *Dizziness-and-balance.com*

WHAT IS ALEXANDER'S LAW?



"KAT" A CASE STUDY:

- SO…What do you think is wrong with Kat???

- Is Nystagmus due to her Concussion, a CENTRAL vestibular dysfunction???
- OR…is her Nystagmus due to a PERIPHERAL vestibular dysfunction???

- SHOULD YOU TREAT HER OR REFER HER FOR ADDITIONAL TESTING???
- IF YOU TREAT HER, WHAT IS HER DIAGNOSIS, AND WHAT TREATMENT???
- IF YOU REFER HER, WHAT IS HER DIAGNOSIS, AND WHERE DO YOU REFER HER FOR TESTING, AND WHAT TESTING WOULD YOU RECOMMEND???

"KAT" A CASE STUDY:

- HERE IS WHAT I DID FOR KAT:

- **First**, I explained my objective findings to Kat & her Mother
  - Spontaneous LBN and positive RIGHT head thrust test
  - Abnormal VOMS consistent with post-concussive syndrome
  - Abnormal Gait & Balance Testing

- **Second**, I explained my hypothesis regarding her potential diagnoses
  - HA, blurry vision, difficulty concentrating, dizziness, imbalance= CENTRAL=Concussion
  - Dizziness, imbalance, blurry vision, LBN= PERIPHERAL= RIGHT peripheral vestibulopathy

"KAT" A CASE STUDY:

- HERE IS WHAT I DID FOR KAT:

- **Third**, I explained the appropriate referral for this condition
  - Called PCP to explain findings & request for Oral Steroids (appropriate if symptoms are present within 30 days from initial onset,) *Furman, et al.*
  - Referred Kat for Diagnostic Testing to Dr. Joseph Furman, Neuro-Otology

- **What Vestibular Diagnostic Tests???**
  - Vestibular Diagnostic testing consists of Audiology assessment of Hearing, Cervical VEMPs, Vestibular ENG (caloric testing), Rotational Chair Testing, Neuro-Vestibular clinical exam with position testing, gaze testing, CN testing, observation of gait and balance.

"KAT" A CASE STUDY:

- Results of Kat's Vestibular Diagnostic Tests: Testing was ~2 months after injury

***Normal Cervical VEMPs** (test the integrity of the Otolith organ-Saccule, Inferior Vestibular Nerve function):

- Aural stimulus in form of ipsilateral loud clicks
- Ipsilateral SCM muscle is tested for myogenic potentials

***ABSENT Caloric response on RIGHT** (ENG/VNG Testing):

-stimulates the Horizontal SCC with separate cold and warm air or water, testing integrity of Superior Vestibular Nerve

-Ice water caloric test used to determine if minimal function exists in patients with severe unilateral vestibular loss

-Kat has a left beating spontaneous vestibular nystagmus

O'Sullivan & Schmitz

"KAT" A CASE STUDY:

- Results of Kat's Vestibular Diagnostic Tests: Testing was ~2 months after injury

***Rotational Chair Testing:**

- Kat has a severe directional preponderance on rotational testing

-Rotational chair tests each HORIZONTAL SCC by rotating subjects in the dark and measuring the amount of nystagmus by comparing VOR gain & phase during rotations toward & away from each ear.

***Position Testing: Dix Hallpike & Roll Testing/Gaze Testing:**

-Kat has a persistent left beating positional nystagmus regardless of position

-Kat does NOT have BPPV

**DIAGNOSIS= Post-Traumatic Right Peripheral Vestibulopathy with a SEVERE, ongoing Vestibular Ocular Reflex Asymmetry in addition to a Central Vestibular Concussion Injury

"KAT" A CASE STUDY:

- AT LAST- Treatment Interventions:
  - Initial PT visit:
    - **Patient Education!!!** Provided printed educational materials from "VEDA" (Vestibular Disorders Association) on Concussion & Post-Traumatic Vestibulopathy
    - **HEP:** Basic Smooth Pursuits, Horizontal & Vertical Saccades, Saccadic Substitution (H/V), Basic standing balance in corner for safety with feet narrow & eyes closed
    - Advised patient & her Mother to schedule appointment with Dr. Furman ASAP, follow up with PCP regarding Steroid prescription & take as prescribed.
    - Schedule Vestibular PT once/week x 8 weeks…

"KAT" A CASE STUDY:

- Second PT Visit:
- Follow up regarding medication, scheduling of appointment with Dr. Furman, HEP tolerance…
- Symptom assessment- HA 4-5/10, Dizziness 4-5/10, Nausea resolving, Imbalance continues, using WW
- Continued with smooth pursuits & saccades, introduced SLOW VOR x 1
- Focused on her static & dynamic balance training & Gait Training
- Assessed Gait with her lofstrand crutches
- Provided new printed HEP for patient
- Education on "expose-recover" model

"KAT" A CASE STUDY:

- Third PT visit:
- Symptom assessment- HA continue to be daily, range 4-6/10 at worst, dizziness continues to decrease, balance slowly improving, continued cognitive slowness noted (diff concentrating), Gait now able to walk with her crutches
- Continued with oculomotor training (pursuits, saccades,) SLOW VOR x 1 with metronome, introduced SLOW VMS
- DGI (Dynamic Gait Index) results- 16/24, indicative of increased fall risk
- Added gait with slow HT, use of focal point needed for balance
- Provided updated HEP

"KAT" A CASE STUDY:

- Fourth PT visit:
- Symptom assessment- HA persistent, rated 4-6/10 at worst, fogginess & cognitive slowing continues, dizziness decreasing daily, imbalance slowly improving, gait with lofstrand crutches also improving
- Repeat VOMS as patient returning to see Neuropsych Doc at Concussion Clinic
- VOMS symptom score improving=35
- Added busy background to oculomotor & VOR/VMS training
- Updated HEP, suggested possible referral for HA management (PM & R)

"KAT" A CASE STUDY:

- Fifth PT visit:
- Patient reports her ImPACT scores are slowly improving, but she still has deficits in all domains: (scores have not returned to baseline.)
- Patient & her Mother have decided that she is not ready to begin her Freshman year of college, and will take the Fall Semester off
- Patient referred to PM&R (Physical Medicine & Rehab MD) for medical management of her persistent HA
- Progressed to VOR + SLOW Gait walking to and from target with lofstrand crutches

"KAT" A CASE STUDY:

- PT Visits 6-12:
- Patient started taking low-dose Nortriptyline for HA management prescribed by PM&R
- Patient continues to have daily HA, range 2-6/10 at worst even with med
- Progressed all VOR & VMS training with use of busy backgrounds & faster speeds on metronome (Normal is 180 beats per minute)
- Progressed all static & dynamic balance activities, working on compliant surfaces
- Eventually progressed patient to independent gait without AD

"KAT" A CASE STUDY:

- PT Visits 6-12:
- Once her vestibular symptoms were decreasing, focus of her PT sessions were largely shifted to dynamic balance training & daily exposures to busy environments.
- Why? Kat has CP, and prior to her concussion, she was working on improving her strength, balance and gait in preparation for college life
- PT sessions consisted of the following activities:
  - Dynamic balance training with use of Airex foam, BOSU ball, rocker board
  - Alternating FW/LAT lunges, clock drills to improve stepping balance
  - Gait training across a variety of surfaces, environments, curbs, stairs (step-ups,) obstacle negotiation with and without lofstrand crutches.
  - Encouraged patient to enroll in yoga classes, joining a gym for wellness and continued flexibility, strengthening and endurance training
  - Encouraged daily exposures to busy environments, as well as optokinetic video training to assist with exposures to busy environments & habituation (she had been avoiding these situations due to her headaches…)

"KAT" A CASE STUDY:

- Kat attended VT for ~ 12 weeks and was transitioned to independent HEP
- Kat's ImPACT scores had returned to her baseline level of cognitive function
- Final VOMS symptom score was "0"
- Normal VOMS- pursuits, saccades, convergence, VOR x1, VMS
- Final cDVA test normal, loss of 2 lines of visual acuity & no symptoms
- Normal mCTSIB testing on floor & on foam
- Final DGI score 22/24, because she was unable to step over an obstacle safely without an AD, stairs are non-reciprocal with use of single HR…Kat also sees a developmental PT for her CP
- Goggle Assessment reveals nearly resolved LBN, as she has "compensated" for her right peripheral vestibulopathy

"KAT" A CASE STUDY:

- OTHER CONSIDERATIONS PERTINENT TO THIS CASE:
  - Kat continues to struggle with daily, chronic, post-traumatic migraine HA
  - Kat has now been referred to Neurology for her HA management at the UPMC Headache Center & has started a different migraine preventative medication, and may be a candidate for Botox injections for her migraine management
  - Kat also sees a Chiropractor for her chronic neck pain & HA post-concussion
  - Kat continues to see her developmental PT for strengthening, balance & gait activities due to her CP
  - Kat attends Yoga regularly & goes to the gym 3 days/week for wellness & HA management…

- "It truly takes a VILLAGE to manage Concussion."

TEAM WORK MAKES THE DREAM WORK…

- Physician – medication management
- Neuropsychologist – Neuro cognitive function / testing (ImPact Test)
- Vestibular Physical Therapist and/or Exertional Physical Therapist

- Neuro-Optometry/Ophthalmology – more complicated eye dysfunctions
- Neuro-Otology – dizziness or symptoms that do not improve
- Psychology/Psychiatry
- Speech Therapy – cognitive rehab/strategies to improve memory or organizing thoughts
- Coach/Athletic Trainer/School Administrator for sport-related concussion
- Parents

REFERENCES:

- Vestibular Disorders Association (VEDA), Concussion info: https://vestibular.org/sites/default/files/page_files/Concussion _0.pdf
- Centers for Disease Control (CDC) HEADS UP Concussion campaign: http://www.cdc.gov/headsup/index.html
- Zurich Concussion Guidelines: http://bjsm.bmj.com/content/47/5/250.full • American Academy of Neurology: www.aan.com/concussion
- American Academy of Neurology, Sports Concussion Resources: https://www.aan.com/concussion

*Ontario Neurotrauma Foundation Guidelines: http://onf.org/documents/guidelines-for-concussion-mtbipersistent-symptoms-second-edition

- www.rethinkconcussions.upmc.com

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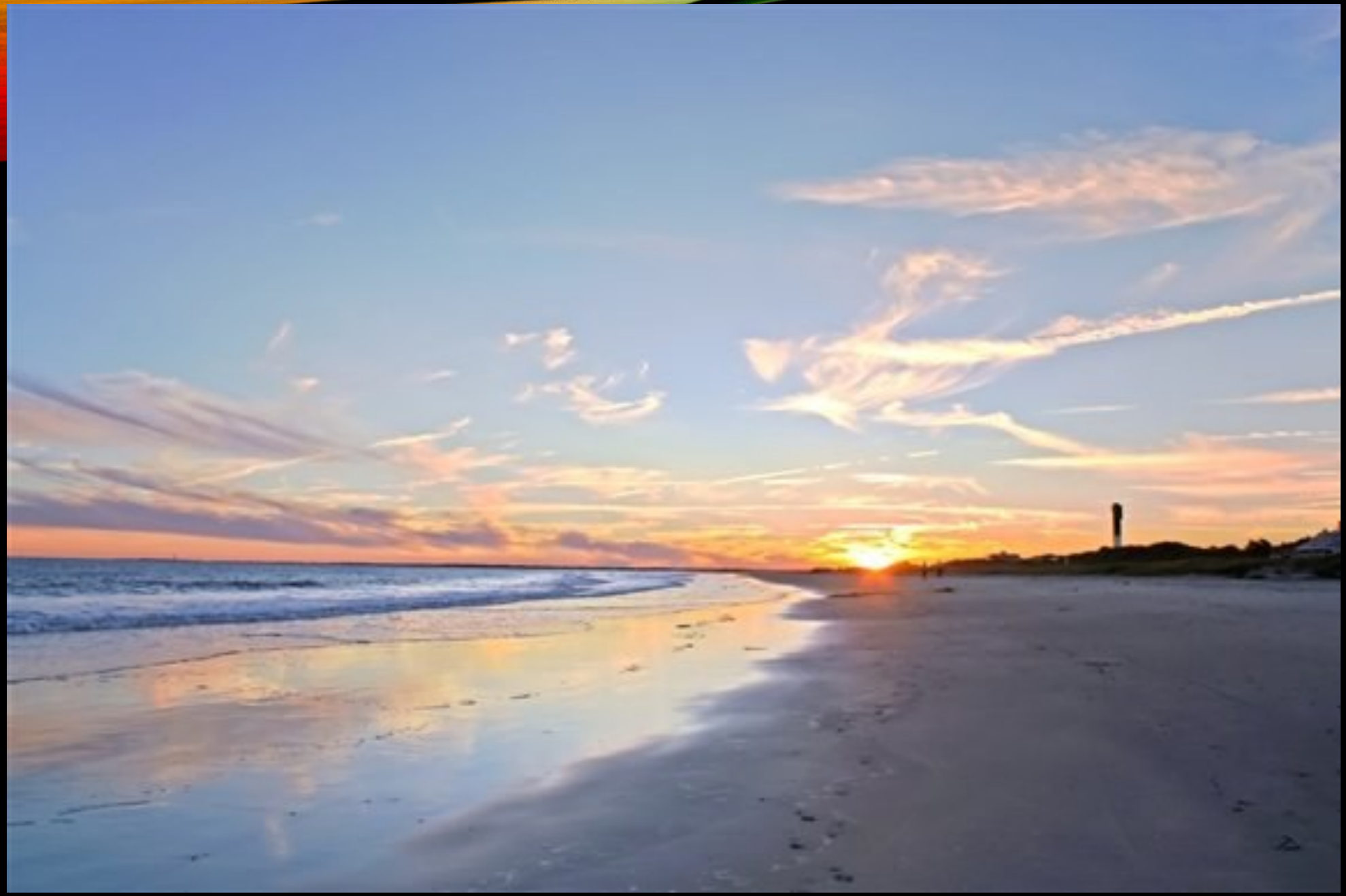
- www.dizziness-and-balance.com; Timothy C. Hain, MD.



THANK YOU!!!