Objectives

- To become familiar with common visual and vestibular deficits following concussion
- To review evidenced practice and new protocols as well as theories behind concussion rehabilitation
- To understand the role of visual and vestibular baseline tests in the management and identification of potential prolonged recovery

Concussion 101…..

Concussion or mild traumatic brain injury (MTBI) is a pathophysiologic process affecting the brain induced by direct or indirect biomechanical forces. Common features include the following:

- Rapid onset of usually short-lived neurological impairment, which typically resolves spontaneously.
- Acute clinical symptoms that usually reflect a functional disturbance rather than a structural injury.
- A range of clinical symptoms that may or may not involve loss of consciousness (LOC).
- Routine neuroimaging studies are typically normal.
Metabolic Crisis

Pathophysiology

NCAA Concussion Statistics

Rates (per 10,000 exposures)

<table>
<thead>
<tr>
<th>Sport</th>
<th>M. Wrestling</th>
<th>M. Ice Hockey</th>
<th>M. Football</th>
<th>W. Soccer</th>
<th>W. Basketball</th>
<th>M. Basketball</th>
<th>M. Wrestling</th>
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Actual # of Concussions Sustained

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<tr>
<th>Sport</th>
<th>Football</th>
<th>W. Soccer</th>
<th>W. Basketball</th>
<th>M. Basketball</th>
<th>M. Wrestling</th>
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From APTE website, Oct 2015
2009/2010-2013/14 academic years
Post Concussion Syndrome vs. Symptoms... The BIG Debate

- Symptoms include:
  - Chronic persistent Headaches
  - Fatigue/Sleep disturbances
  - "Fogginess"
  - Personality changes (irritability, depression)
  - Sensitivity to light or sounds
  - Dizziness when standing quickly
  - Academic functioning: Short term memory deficits, difficulty with problem solving, concentration, and processing speed.
  - Can be very disabling for the individual and their families

- Typically defined as having concussion symptoms that last for greater than a month after the initial head injury but WHO vs CDC have different criteria currently

Second Impact Syndrome

- Rare fatal phenomenon involving a 2nd head injury before resolution of 1st
- 1st concussion could have been mins, days or weeks prior
- 2nd blow only have to be "minor"
- Sudden collapse and rapid neurological decline
- Results in severe death and/or impairment
- Thought to be caused by subdural hemorrhage and/or dysautoregulation of the cerebral vasculature causing hyperemic brain swelling and elevated ICP
- Adolescents and young adults

Role of Athletic Trainers in Concussion Management

- As licensed medical professionals, athletic trainers receive comprehensive didactic and clinical training in concussion management.
- They are typically the first providers to identify and evaluate injured persons and are integral in the post-injury management and return-to-play (RTP) decision-making process
Role of Pre-season Preparation

- Risk Factors
- Education
- Baseline Concussion Testing
- Emergency Procedure Protocol

New Developments.....

- Looking at baseline vestibular and oculomotor scores using VOMs
- Reliability and Associated Risk Factors for Performance on the Vestibular/Ocular Motor Screening (VOMS) Tool in Healthy Collegiate Athletes.
  - The VOMS possesses internal consistency and an acceptable false-positive rate among healthy Division I collegiate student athletes.
  - Female sex and a history of motion sickness were risk factors for VOMS scores above clinical cutoff levels among healthy collegiate student athletes.
  - Results support a comprehensive baseline evaluation approach that includes an assessment of premorbid vestibular and oculomotor symptoms.
Risk Factors

- Several risk factors contribute to an athlete’s concussion recovery.
- Assessing the athlete’s concussion history can provide valuable information; specifically, the number of concussions, the severity of each concussion, and how close in time the concussions occurred to each other.
- Additionally, assessing concussion symptoms (number, severity, and duration), the age of the athlete, and any pre-existing conditions (e.g., history of migraines, headaches, ADD/ADHD, Learning Disability, Depression, Anxiety) before the season begins can help with managing a concussion if it ever occurs.

What is YOUR State’s Law?

- All 50 states have a Concussion Law
- Who can return individuals to play?
- In the states of KS
  - Kansas law requires a physician’s signature (MD/DO) to “Return to Play.”
  - [http://www.kansasconcussion.org](http://www.kansasconcussion.org)

ImPACT Testing
Risk Factors

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Sideline Assessments

• SCAT 3
• Child SCAT 3
• SCAT 2 (mobile app)
• Sideline Impact Test (mobile app)
• NFL Sideline Tool
• SAC
• King-Devick Test

Return to Play Protocol... stay tuned may be changing

http://blogs.bmj.com/bjsm/files/2013/11/RTP1.jpg
Typical Recovery

• 85-90% Concussions show signs of recovery in first 7-10 days
• 80% of Concussions fully recovered in 3-4 weeks
• What about the rest?
• Early identification of impairments aids in return to activity/sport without prolonged sequelae

Predictors of Prolonged Recovery?

Published in the Journal of Pediatrics 2013:

“Symptoms Severity Predicts Prolonged Recovery after Sport-Related Concussion, but Age and Amnesia Do Not”

Boston Children’s and University of Pittsburgh Medical Center studied a total of 182 patients that presented to their clinics within three weeks of injury.

*****We need to listen to the initial symptoms (especially headaches, dizziness and fogginess) described versus considering sex, age, loss of consciousness, and amnesia when discussing length of recovery

Symptomatic Recovery Period

• Reassurance/Education
• No exercise (24-48 hours only?)
• Decreased school activity/hours (based on symptoms)
• Do not want decompensation
• Role of added stressors?
• Each case is individual, no 2 concussions are the same
• PATIENT EDUCATION!!!
Multidisciplinary Approach

From withdrawal to return to play:
- Coach
- Athletic Trainer
- Sports Medicine Doctor
- Neuropsychologist
- Neurologist
- Vestibular Therapist (PT/OT)
- Vision Therapist
- Neuropathologist
- Counselor

UPMC Concussion Trajectories

Conceptual Framework.... UPMC
Not a perfect World

- Subtypes RARELY occur in isolation and often overlap
  - The KEY is finding the "driving" subtype(s) to start management

Medical History is Key!

- Migraines
- Prior Concussions
- Visual Impairment
- Cervical Injury/Impairment
- Learning Disabilities
- Mood Disturbances

Clinical Pattern Recognition in Concussion

- What are your patient's symptoms?
  - Dizziness
  - Vestibular
  - Cervical
  - Cognitive
  - Post-Traumatic Migraine
  - Anxiety/Mood
  - Exertional
Common Symptoms in Ocular Deficits

• Difficulty focusing/ prolonged reading
• Double vision
• Blurry vision
• Eye strain
• Headaches
• Pulling around eyes
• Sensitivity to light

Oculomotor Dysfunction Following mTBI

<table>
<thead>
<tr>
<th></th>
<th>mTBI</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td>Convergence Insufficiency</td>
<td>55%</td>
<td>5%</td>
</tr>
<tr>
<td>Saccadic Impairment</td>
<td>30%</td>
<td>0%</td>
</tr>
<tr>
<td>Pursuit Impairment</td>
<td>60%</td>
<td>0%</td>
</tr>
<tr>
<td>Ocular misalignment (vertical phoria)</td>
<td>55%</td>
<td>5%</td>
</tr>
<tr>
<td>Ocular misalignment (horizontal phoria)</td>
<td>45%</td>
<td>5%</td>
</tr>
<tr>
<td>Accommodative dysfunction</td>
<td>65%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Capo-Aponte et al. Military Medicine 2012

Oculomotor System

• Purpose: to produce eye movements to direct the fovea toward the target of interest
• 6 extraocular muscles rotate the eye
  • Divided into 3 pairs with complementary actions
• 3 cranial nerves control the eye muscles
  • CN III (oculomotor): Medial rectus, superior rectus, inferior rectus and inferior oblique
  • CN IV (Trochlear): Superior oblique
  • CN VI (Abducens): Lateral rectus
Visual Assessment

- Visual acuity
- Extra-ocular movements
- Pursuit eye movements
- Saccades
- Vergence
- Accommodation
- Gaze holding (nystagmus)
- Ocular alignment

Ocular Motor findings – Post Concussion:

**Pursuits:**
- “Saccadic” pursuits or “Saccadic Intrusions”
- Symptomatic e/j pursuit movements

**Saccades:**
- Hypometric Saccades
- Slowed Saccades
- Symptomatic w/ saccades eye movements

Abnormal Smooth Pursuits
Vergence System Issues

- Convergence: Ability of eyes to turn inward to focus on a near target
- Vvergence Testing: Patient fixates on target brought in along the mid-sagittal plane toward the nose
- Near Point of Convergence: when target becomes double
  - Normal NPC ≤ 6 cm from tip of nose
  - (Scheiman 2003)
- Abnormalities in Vvergence
  - Convergence Insufficiency = reduced vergence response (≥ 6 cm from tip of nose)
  - Convergence Spasm = increased vergence response

Convergence

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Convergence
Convergence Is Linked to Neurocognitive Functioning

- Methods: A total of 78 athletes (mean age, 14.31 ± 2.77 years) who were seen a mean 5.79 ± 5.63 days after an SRC were administered 3 trials of an NPC assessment, along with neurocognitive (Immediate Post-Concussion Assessment and Cognitive Testing [ImPACT]) and symptom assessments. Patients were divided into normal NPC (NPC >5 cm; n = 45) and CI (NPC <5 cm; n = 33) groups. Intraclass correlation coefficients (ICCs) and repeated-measures analyses of variance (ANOVAs) assessed the consistency of NPC across the 3 trials. The ANOVAs were employed to examine differences on neurocognitive composites and symptoms between the normal NPC and CI groups. Stepwise regressions (controlling for age and symptom scores on the Post-Concussion Symptom Scale [PCSS]) were conducted to examine the predictive utility of the NPC distance for neurocognitive impairment.

- Results: Groups did not differ on demographic or injury characteristics. NPC differed between trial 1 and trials 2 (P = .02) and 3 (P = .01) for the CI group but not the normal NPC group. Internal consistency was high across NPC measurements (ICC range, 0.95-0.98). Patients with CI performed worse on verbal memory (P = .02), visual motor speed (P = .02), and reaction time (P = .001, R² = .13) and had greater total symptom scores (P = .02) after the injury. Results of hierarchical regression revealed that the NPC distance contributed significantly to the model for reaction time (P < .001).

- Conclusion: CI was common (~42%) in athletes evaluated within 1 month after an SRC. Athletes with CI had worse neurocognitive impairment and higher symptom scores than those with normal NPC. Clinicians should consider routinely screening for NPC as part of a comprehensive concussion evaluation to help inform treatment recommendations, academic accommodations, and referrals for vision therapy.

Vergence Dysfunction

- General Symptoms
  - Asthenopia when reading
  - Frontal headaches
  - Intermittent or constant double vision
  - Squints, crosses one eye
  - Letters will appear to float or move around the page
  - Lack of symptoms but findings persist
  - Suppression, avoidance, or occlusion (pre-existing?)

- Common Vergence Problems
  - Convergence Insufficiency
  - Convergence Excess
  - Convergence Spasm

Convergence Insufficiency

- Symptoms:
  - "Double" or blurred vision at a reading distance
  - Eye strain while reading
  - Frontal headaches
  - Pounding around the eyes

- Definition: Sensory and neuromuscular anomaly of the binocular vision system, characterized by an inability of the eyes to turn towards each other or sustain convergence. Also, when there is a tendency of the eyes to deviate outward (exophoria), not age dependent.

- Non-TBI Cohort: prevalence up to 6% in general population. Much greater in mTBI cases.

Convergence Insufficiency

Difficult Environments

Misalignment Issues

OCULAR MISALIGNMENT

- Tropia – overt deviation of the eye
  - Exo – outward (laterally)
  - Este – inward (medially)
  - Hyper – upward
  - Hypo – downward

- Phoria – Ocular deviation occurs when dissociation occurs.
Alternate Cross Cover Test

Misalignment Symptoms:

If Severe:
- Diplopia
- Head tilt (vertical misalignment)
- Noticeable eye turn

If Subtle:
- Difficulty maintaining focus
- Cosmetically normal
- Ocular soreness
- Headaches
- Mental dullness

Areas Responsible For Binocular Function
Vestibular/Ocular System Deficits – Present in Concussion

- Disruption of both static and dynamic balance contributing to postural instability
- Symptoms can be:
  - Dizziness/Vertigo
  - Motion Sensitivity/ Height Phobia
  - Tinnitus
  - Lightheadedness
  - Blurred vision/Double vision/Trouble Focusing
  - Photophobia
  - Imbalance (especially in dark)

Dizziness Post Concussion

Prevalence and Significance

- Dizziness reported in 55% of concussed athletes (Lovell 2004)
- Ocular impairments (blurred vision, diplopia, difficulty reading, etc.) seen in 36%
- Dizziness associated with protracted recovery
- Undiagnosed vestibular deficits may delay recovery

Causes of Vestibular Dysfunction

<table>
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<tr>
<th>Diagnosis</th>
<th>Possible Manifestations</th>
<th>Comment</th>
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<tbody>
<tr>
<td>Labyrinthine Concussion</td>
<td>Ataxia, imbalance, BPPV may be present</td>
<td>Most common vestibular injury due to TBI</td>
</tr>
<tr>
<td>Skull Fracture</td>
<td>UCL deficit (peripheral complete) Conductive hearing loss May have mixed peripheral and central lesions</td>
<td>Common with blows to the occiput, temporal or parietal regions</td>
</tr>
<tr>
<td>Hemorrhagic Labyrinthitis</td>
<td>May create post-traumatic hydrops (Ménière’s type syndrome) Damage to labyrinth may create acute vertigo and bilateral hearing loss</td>
<td>Labyrinthitis damage may present with signs and symptoms similar with acute peripheral vestibular damage</td>
</tr>
<tr>
<td>Hemorrhagic Trauma</td>
<td>Occlustion signs, poor smooth pursuit, vertigo, perception of tilt</td>
<td>Damage to vestibular and oculomotor nuclei</td>
</tr>
<tr>
<td>Increased Intracranial Pressure</td>
<td>Fluctuating hearing, ataxia, imbalance</td>
<td>May cause peri-lymphatic fistula</td>
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</table>
Ears and the Brain... Connection

- Head movements are detected by the cupula and transmitted via the Vestibular Nerve to the Brain. Which then controls eye movement to stabilize the gaze.

- The ratio of eye to head movement (GAIN) should be 1:1. Abnormal gain can cause symptoms of blurry vision or vertigo.

Central Processing Proprioceptive Input

Motor Outputs

- VOR (Vestibular Ocular Reflex): generates eye movements, which enables clear vision while head is in motion.

- VSR (Vestibular Spinal Reflex): generates compensatory body movement in order to maintain head and postural stability, thereby preventing falls.
**Dynamic Visual Acuity (VOR)**

![Graph showing VOR results](http://www.eastneurology.com.au/images/BPPV%202.jpg)


**Migraine Related Dizziness (Jeong et al, 2010)**

Meta-analysis (Furman et al, 2003) - 534 migrainers:
- Unilateral caloric reduction - 39%
- Spontaneous nystagmus 50%
- Positional nystagmus - 20%
- Directional preponderance - 50%
- Abnormal postural stability - approx 30%

Migraine-related dizziness may be the most common disorder presenting to specialty clinics for dizziness, vertigo and disequilibrium (Neuhauser et al, 2009)

Hypersensitivity of the Vestibular System speculated
Vestibular Migraine Complicated

- Hard to identify… may not report “true headache”
- 114 consecutive post concussion patients who were referred for balance/vestibular rehabilitation
- Significant improvements achieved following standardized outcome measures of balance/vestibular function:
  - Activity-Specific Balance Confidence Scale
  - Dizziness Handicap Inventory
  - Gait Speed
  - Computerized Dynamic Posturography – Sensory Organization Test
  - Dynamic Gait Index
  - Functional Gait Assessment
  - 5 Times Sit to Stand (Alsalaheen 2010)

Visual Motion Sensitivity Issues

- Vision is in the Brain – facilitated by the eyes
- The visual world is a mental construction
- Constructing a visual world requires energy and effort
- ½ of the cerebral cortex is devoted to the task
- Visual processing accounts for 44% of the brain’s energy consumption

VISUAL PROCESSING

- Visual processing is BI-MODAL
  - Spatial/Ambient or Magnocellular
  - Where am I?
  - Where is it?
  - Porcine lobe
  - Parietal lobe
  - What is it?
  - Temporal lobe
How Does this All Work?

- Spatial/M Pathway
  - Proactive
  - Lighting Fast
  - Subconscious
  - Movement
  - Spatial Localization
  - Figure-Ground Segregation
  - Larger Impact on balance/posture/function
  - Anticipates change in preconscious

- Focal/P Pathway
  - Reactive
  - Slower
  - Cortical/Higher Level/Processing
  - Object Identification
  - Guidance of the Fine Motor
  - Spatial Localization
  - Secondary to Ambient Process in Survival

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Binocular Occlusion

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WARNING!!!

Pencil Push Ups
- Do NOT do in Acute Phase > Focal Binding
- If send home for practice make sure they have someone watching them.
- Optometrists do not send home pencil push ups because they lack the neuro-cognitive link.
Focal Binding and Motor Skills

- Focal Binding compromises preconscious/proactive relationship between magnocellular processing and motor
- Movement becomes conscious and isolates function (lack of automaticity)
- No fluency because system is unable to anticipate
- May have intact peripheral field but no peripheral awareness

MAGNO and PARVO Balance

- Need to be able to use the spatial (magna) and focal (parvo) systems together and switch back and forth easily between the 2 systems
- Neurological events affect the balance between the 2 systems
- An imbalance between the 2 processes results in information being by the occipital cortex without spatial pre-programming = poor anticipation/motor planning

How Does This Make You Feel?
How Do We Train This?

• All sensory systems working together!

Physical Therapy Concussion Eval: The Whole Picture

• Subjective Questionnaires: DHI, ABC Scale, MDI, HIT-6
• Complete history of event – LOC, directions of hit, amnesia, removal from play, on-field symptoms
• Prior concussions, history of mood disorders (anxiety, ADHD, ADD), migraines, learning disabilities
• History of visual impairments
• Management since injury? (cognitive rest, days off school/work, medications, testing)
• Full post-concussion medical history
• Complete Vestibular/Ocular Evaluation
• Cervical Spine Evaluation

Concussion Exam Components

- Cervical Range of Motion
- Cervical Gating
- General Extremity Strength Screening
- Fine Motor Coordination Assessment
- Finger to Nose Test
- Finger to Object Test
- Finger to Forehead Test
- Finger to Object Test

- Head Shaking Nystagmus
- Do-the-disbliss Test (rule out BPPV)
- Valsalva/Ballottement
- Dix Hallpike and Roll Test (rule out BPPV)

- Motion Sensitivity Quotient
- Modified Balke Protocol/ Buffalo Treadmill Test

- Visual Acuity
- Optokinetic Nystagmus
- Spontaneous Nystagmus
- Smooth Pursuit
- Saccades
- Vestibular Ocular Reflex
- Head Thrust Test
- VOR Cancellation
- Convergence
- Convergence Abnormal Testing
- Dysreflexia Nystagmus
- Field Caselli Nystagmus
- Vertical Head Thrust Test
- VOR Cancellation
- Convergence Abnormal Testing
- Convergence Abnormal Testing
Visual Acuity/Dynamic Visual Acuity

Visual acuity (VA) is acuteness or clearness of vision, which is dependent on the sharpness of the retinal focus within the eye and the sensitivity of the interpretative faculty of the brain.

**Visual Acuity**
- Static

**Dynamic Visual Acuity** - DVA

- **Computerized DVAT**
  - **InVision**
  - **The Dynamic Visual Acuity (DVA) Test**
    Quantifies the impact of vestibular ocular reflex (VOR) system impairment on a patient’s ability to perceive objects accurately while moving the head at a given velocity on a given axis.
  - **Gaze Stabilization Test (GST)**
    Quantifies the range of head movement velocities on a given axis over which a patient is able to maintain an acceptable level of visual acuity.
Balance and Gait Assessment

- Romberg, Sharpened Romberg, Single Leg Stance
- Sensory Organization Test (Balance Master)
- Modified CTSIB
- BESS Test
- Dynamic Gait Index
- Functional Gait Assessment
- HiMAT (relatively new for higher level TBI)
- Computerized Posturography... Neurocom

Buffalo Treadmill Test
Use of Buffalo Concussion Treadmill Test

Differential Diagnosis of Exertional Symptoms

What We’ve Learned......

- It is more than just balance
- Vestibular/Ocular Component is missing Link
- On Field Markers that Predict Complicated Recovery?
- Outcomes are highly variable
- Vestibular-related symptoms (dizziness/fogginess) and migraine history/symptoms best predict protracted recoveries
- Effective sideline management is key- removal from play a must when symptoms occur
- Return to play prior to full recovery from concussion will result in worse outcome and risk for causing re-injury.
- Neurocognitive testing is an effective tool to help quantify the injury and guide the management and RTP process.
- "Mild" injuries may become complicated and the "severe" injuries may become mild
- Proper Clinical management is best form of prevention
- Targeted clinical pathways for treatment and rehabilitation are being established
Role of Vestibular/Ocular Rehab
Return to Play/Activity

• Does the patient have skewed/blurred vision while body in motion/head turning?
• Do they have continued headaches?
• Do visual tasks increase their symptoms?
• Critical missing link of full sensory integration of visual / vestibular / somatosensory system?

You Have To Train All Systems!

TEAM EFFORT!
- Conjugate movement (EOM movement, SACCADIES and PURSUITS), disconjugate movements (CONVERGENCE and DIVERGENCE), the FIXATION system, accommodation and VOR control the position of an image on the fovea.

Where Do I Start?

• Ocular?
• Vestibular?
• Cervical?
• Exertional/Fatigue?
Rehabilitation

Vision: saccades, convergence, ocular alignment, tracking
Vestibular: VOR, VSR, Balance, motion sensitivity
Cervical: ROM, manual, pain control, posture, proprioception
Exertional: Buffalo Treadmill Test > treatment

Train All Together!!!!

Concussion Rehab Focus

- Fine Motor Deficits/Reaction Time
- Vision
- Eye head coordination
- Headaches
- Fatigue
- Balance/Coordination
- Dual task performance
- Body Mechanics and Posture
- Safe return to activity

Convergence Exercises

- Pencil Push Ups (do not overtrain!)
- Brock String
- Arrow Chart/Dot Card
Motor Control Exercises

Cervical Stabilization with Visual Feedback

Adaptation Exercises

- VOR x 1 and x 2 viewing exercises
- Progression:
  - Duration: goal up to 2 minutes continuous
  - Velocity
  - Patterned/busy backgrounds
  - Position
  - Target Distance
Substitution
- Substitution of other strategies to replace the lost or impaired function
  - Eye tracking
  - Oculomotor Exercises
  - Saccades
  - Eye head coordination exercises
  - Remembered Targets

Cheap Dynavision......

Substitution Exercises
Using laser: eyes first then head, how accurate, add compliant surface
Cervical Proprioception with Oculomotor Component

Saccades with Balance and Cervical Proprioception

Cervical Proprioceptive Exercises

- Head Laser with Targets
- Combine with Saccades
- Eyes Closed awareness
Progression

- Adaptation (if there is something to adapt)
- Substitution (this includes oculomotor component)
- Habituation
- Add balance component into all of above or separately

What About Visual Motion Sensitivity?

Factors that may trigger or exacerbate headaches

- Cervical spine injury
- Impaired sleep
- Higher level cognition
- Vision
- Hearing sensitivity
- Exercise
Questions?

References
References


