Concussion – An Evidence-Based Approach to Optometric Management

Objectives

- Give a brief overview of the evolution of the current definition and pathophysiology of concussion
- Discuss current paradigms (or lack thereof) for vision screening after concussion by non-optometric providers
- Go through the most common visual signs and symptoms seen after a concussion and their timelines for resolution (acute vs. chronic – PCS)
  - Afferent Visual Pathway (Ocular Health, Color Vision, Visual Fields, Pupils, Refractive Error)
  - Efferent Visual Pathway (Ocular motility)
  - Higher Order Pathways (Visual processing)
- Current/Future role for vision in concussion

Glasgow Coma Scale (GCS)

- Motor Response
  - (4) Withdraws from noxious stimuli
  - (3) No response
  - (2) Extension response
  - (1) Abnormal flexion
  - (0) Localizes to noxious stimuli
- Verbal Response
  - (4) Confused, yet coherent speech
  - (3) Inappropriate words and jumbled phrases
  - (2) Incomprehensible sounds
  - (1) No sounds
- Eye Opening
  - (6) Obeys commands fully
  - (5) Localizes to noxious stimuli
  - (4) Eyes open to speech
  - (3) Eyes open to pain
  - (2) Eyes open
  - (1) No eye opening

Level of TBI

- Mild (13-15)
  - +/- loss of consciousness < 30min
  - Normal neuroimaging
- Moderate (9-12)
  - Loss of consciousness > 30min, < 24hrs
  - Normal/abnormal neuroimaging
- Severe (3-8)
  - Coma
  - Normal/abnormal neuroimaging
  - Vegetative (0)

Concussion - Controversy over a “Definition”

- +/- Loss of consciousness
- +/- Direct blow to the head
- Rapid onset of short-lived impairment of neurological function that resolves spontaneously
  - HOWEVER, signs and symptoms may evolve over minutes to hours in some cases
- Acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury
  - HOWEVER, it may result in neuropathological changes
- Resolution of clinical features typically follows a sequential course
  - HOWEVER, in some cases it may be prolonged

An ever-changing definition

Traumatic Brain Injury - Pathophysiology

- Primary traumatic brain damage
  - Mechanical forces → tissue deformation AT the moment of injury
  - Direct damage to blood vessels, axons, neurons, glia, etc
  - Diffuse axonal injury (DAI)/vascular injury (DVI)
  - Focal Injury
    - Intracerebral, subdural, extradural, subarachnoid injury
    - Axonal injury
    - Contusion
    - Laceration
- Secondary traumatic brain damage
  - Complication of primary damage
    - Ischemic and hypoxic damage, cerebral swelling, increased intracranial pressure, infection, etc

TEAM Approach to Concussion - 2015

- Multidisciplinary Assessment
  - Review mechanism of injury
  - Relevant medical history
  - Symptom Checklist
  - Neurocognitive Screening/Neuropsychological Evaluation
  - Balance Assessment
  - Vestibular Screening/Examination
  - Neurological Evaluation
  - Cervical Spine Evaluation
  - Psychological Evaluation
  - Neuroimaging pmn

Pediatric Concussion - What we do know -

- Children and adolescents have longer recovery times than adults
- Expected duration of symptoms associated with sports-related concussion <4 weeks
- Prolonged recovery is defined as symptomatic for >4 weeks
- Mechanism for longer recovery time is unknown
  - Proposed to be due to differences in response to excitotoxic injury by developing adolescent brain


Pediatric Concussion – What we don’t know -

- Minimal clinical trials in pediatric concussion
- Literature does not address how to manage different age groups of children differently from adults

Epidemiology of Concussion

- CDC 2010 - 2.5 million people went to ER for TBI based on ICD9 data
  - 33% mTBI
  - Underreporting since only includes those who presented to the ER and had a relevant diagnostic code (Voss)
  - Pediatric population
    - 173,285 <19yo nonfatal concussions annually 2001-2009
    - Increase from 153,375 to 248,418
  - Most common mechanism – Falls
  - High Risk Populations
    - Military
    - Athletes
    - 1.6-3.8 million SRCs annually
    - 5.8% of all collegiate injuries,
    - 8.9% of high school injuries

www.cdc.gov/traumaticbraininjury


www.cdc.gov/traumaticbraininjury

### Epidemiology

- US Centers for Disease Control and Prevention
  - 173,285 children and adolescents <19 years old treated for a nonfatal recreation and sport-related concussion in ERs annually from 2001-2009
  - Increase from 153,375 (2001) to 248,418 (2009)
- 4 million children present with concussion to emergency rooms annually worldwide
  - Estimated to represent only 12% of children with concussion
  - Estimated that 33 million children sustain a concussion worldwide

### Common Diagnostic/Screening Tests for Concussion

- Self-report Symptom Checklists
- Brief cognitive assessment
  - Standardized Assessment of Concussion (SAC)
  - Sport Concussion Assessment Tool 5 (Child SCAT5)
- Balance/Gait Tests
  - Tandem Gait Test (TGT)
  - Balance Error Symptom Score (BESS)
- Computer Based Neuropsychological Tests
  - ImPACT
  - CogSport
- Headache
- Oculomotor Sideline Screener
  - King-Devick

### Limitations/Difficulties in Concussion Diagnosis and Management

- No structural injury on conventional neuroimaging
- Advanced neuroimaging can show functional/structural damage BUT S$ and not readily available
- Under/over reporting of symptoms worldwide
- Under/over diagnosis
- Evolving definition
  - Subjective nature of diagnosis
  - Symptom Scales
  - Intentional low baseline scores
  - Incomplete understanding of pathophysiology
  - Lack of data
  - Variability among physicians

### Why does diagnosis matter?

**Trumatic head injuries**

- Brain tissue: edema, contusions, hemorrhage, ictus
- Intact skull: impedes CSF flow and increased ICP
- Concussion
  - Brain deformation, axonal stretch
  - Cerebral edema
  - Diffuse axonal injury
- Second impact syndrome
  - Pronounced, prolonged head trauma
  - Increased ICP
  - Poor outcome

**Concussion**

- Traumatic brain injury resulting in neurobehavioral symptoms
- Common in football and soccer

**Chronic Traumatic Encephalopathy**

- 1) Objective biomarker for brain dysfunction
  - Protein tau
  - 4-repeat amyloid precursor protein
- 2) Treatment of concussion

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**Notes:**

- Why does diagnosis matter? [Link](http://www.bu.edu/cte/about/what-is-cte/)

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**Chronic Traumatic Encephalopathy**

- Objective biomarker for brain dysfunction
- Treatment of concussion
Visual Pathways in the Brain

Post-Concussive Visual Signs and Symptoms

- Currently Screened
  - Double Vision
  - Blurred Vision
  - Light Sensitivity

- In Addition/Actuality
  - Reading Difficulties
  - Eyestrain/Fatigue
  - Eye focusing problems
  - Eye Tracking Problems
  - Vision-Derived Nausea
  - Visual Inattention
  - Visual Anxiety/Crowding


Afferent Visual Pathway

Post-Concussion Visual Signs

Ocular Health
- Traumatic Iritis
- Traumatic Optic Neuropathy
- Retinal changes
- Commotio Retinae
- Retinal Tear/Detachment

Pupil Findings
- Afferent
  - Increased average constriction latency
- Efferent
  - Parasympathetic
  - Increased average constriction velocity
  - Sympathetic
  - Decreased pupil diameter
  - Slower peak dilation velocity
  - Anisocoria?


Thagard-F Cliffhanger K. Pupillary responses to light in chronic non-blast induced mTBI. JOTI. 103(1):25-34.
**Photophobia - Light Sensitivity**

**Etiology?? – Photophobia pathway?**
- Ocular Photophobia
  - Irrits
  - Flash light test
  - Asymmetric
  - Pupil problems
  - Dry Eye
- Neurological Photophobia
  - TBI
  - Migraines
- Pharmacologic

**Management**
- Sunglasses outside OKAY
- Sunglasses inside – TRY TO AVOID
  - Wearing dark glasses indoors → dark adaptation of the retina → aggravation of light sensitivity
- Visors/Hats
- Mild Tints
  - Wavelength matters

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**Visual Signs it may be MORE than a Concussion**

- Pupils
  - Dilated/Fixed
  - APD
  - Anisocoria
- Reduced BCVA
- Visual Field Defects
- Cranial Nerve Palsy
- Ocular Health Problem
  - Optic nerve edema, pallor, etc

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**Efferent Visual Pathway**

CN III, IV, VI, Parasympathetic, Sympathetic - Eye Movements


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**Vestibulo-ocular dysfunction in pediatric sport-related concussion (SRC)**

- Retrospective review of all patients with acute SRC (presenting 30 days or less post injury) and PCS (3 or more symptoms for at least 1 month) referred to a multidisciplinary pediatric concussion program from 9/2013-7/2014
- Methods - Clinical Hx, Physical, PCSS, VOD
  - VOD Complaint (dizziness, blurred vision, etc) + Sign (Abnormal pursuits, saccades, VOR)
- Results - n=101, age 14.2 +/-2.3 years, 76.2% with acute SRC (n=77) and 23.8% with PCS (n=24)
  - Mean duration of sx was 40 days for pts w/ acute SRC and VOD vs. 21 days for acute SRC without VOD.
- Conclusions: Evidence of VOD in acute SRC and PCS.
  - VOD was a significant risk factor for development of PCS

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**What Determines Concussion Resolution?**

- Balance Recovery <7 days
- Symptom Scores 5-14 days
- Cognitive Recovery 7-21 days
- Oculomotor Recovery 21-28 days

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**Role of Eyes in Concussion Diagnosis: VOMS (Vestibular/Ocular Motor Screening) Assessment**

Vestibulococular/Ocular Domains Assessed
- 1. Smooth Pursuit
- 2. Horizontal and Vertical Saccades
- 3. Convergence
- 4. Horizontal and Vertical VOR
- 5. Visual Motion Sensitivity

- 61% of adolescent concussed athletes reported symptom provocation after at least 1 VOMS item
- All VOMS items were positively correlated to the PCS (Post Concussion Symptom Scale) total symptom score
- VOMS was nearly 90% accurate in identifying patients with concussion from controls

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**What Determines Concussion Resolution?**

Other Factors
- Litigation
- Worker’s Compensation
- Individual Motivation (Athlete, Military)
- Age
- Gender
- Concussion History
- Premorbid Factors
- Injury Severity
- Type/Timing of Treatment

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VOMS Continued...

- Women have higher VOMS scores than males (Sufrinko 2017)
- Symptom provocation/clinical abnormality associated with all domains (except convergence and accommodation) can delay recovery time after SRC in youth and adolescents (Anzalone 2017)
- VOMS does NOT provoke vestibular symptoms in healthy adolescents (Yorke 2017)
- VOMS measures unique aspects of vestibular-ocular function other than those measured in the BESS (Balance Error Scoring System) or KD (King-Devick Test) with good reliability (Yorke 2017)
- In collegiate athletes, VOMS had a high internal consistency with an 11% false-positive rate at baseline – mostly female or history of motion sickness (Kontos 2016).


Normal Smooth Pursuits

- VIDEO

Abnormal Pursuits (i.e. Saccadic Intrusions)

- VIDEO

Symptoms: Difficulties reading, nausea with visual motion, difficulties scrolling on a screen

Normal Saccades

- VIDEO
Abnormal Saccades – Hypometric/Hypermetric

- VIDEO

Symptoms: Difficulties reading, difficulties “tracking”, losing place while reading, re-reading

Cal has really great athletes. They are smart and enjoy going to class and to practice. When they are not on the field they are in the library.

Cal has really great athletes. They are smart and enjoy going to class and to practice. When they are not on the field they are in the library.

King-Devick

fMRI of Acute Oculomotor Deficits in Concussed Athletes

- n=9, 7 days post-concussion
  - n=9, age, sex match normal volunteers
  - Fixation, reflexive saccades, anti-saccades, memory guided saccades, self-paced saccades
  - fMRI: widespread increased activation of multiple brain areas following concussion in response to oculomotor tasks
  - Longer latency time, worse position errors, fewer number of self-paced saccades

Accommodation

- When the eye changes refractive power by altering the shape of the lens to focus on objects at different distances
- ie – How the eye focuses on things

Accommodative Pathway

![Accommodative Pathway Image](http://what-when-how.com/neuroscience/the-cranial-nervous-organization-of-the-central-nervous-system-part-4/)

Accommodative Insufficiency

In the eighteenth century was judged with respect to the existing state of the medium. What mattered was the kind of tempo that made, the unexpected social elements. It brought into us, the was to explain the conventions of the genre or the tradition. The prize at the end of the redemption was a different sense of what art could be, a new realm of possibility for the aesthetic. Today all that has changed, definitively. The backing against which art now stands is a particular state of society. What an installation, a performance, a concept or a mediated image can do is to mark a possible or real shift with respect to the laws, the customs, the measures, the moral, the technical and organizational devices that define how we must behave and how we may relate to each other at a given time and in a given place. What we look for in art is a different way to live, a fresh chance at communication. How does that chance come to be? Expression unaches effect, and effect is what teaches. Presence, gesture and speech transform the quality of contact between people, they create both bonds and junctions; and the expressive techniques of art are able to multiply those immediate changes along a thousand pathways of the mind and the senses. An artistic event does not need an objective judge. You

Accommodative Infacility

![Accommodative Infacility Image](image)

Accommodative Spasm

There once was a little girl who could see, read very well. She complained that the print was blurry and moving. She could not keep her place on the page. She went to her optometrist to get help. Her optometrist recommended vision therapy and told the girl that there was a solution to her vision problems. The girl began with vision therapy and saw drastic improvements in her reading, writing, and most of all how she saw the world. The vision therapy made a huge difference in her life.

Convergence/Divergence

![Convergence/Divergence Image](image)
NPC (Near Point of Convergence)

- VIDEO

Convergence Insufficiency

**Vergence Dysfunction**

Double vision can look like this:

Double vision makes it difficult to read and comprehend.

**Convergence Insufficiency Treatment Trial**

CITT Study Group

- Randomized clinical trials looking at the different treatment methods compared to placebo for convergence insufficiency and accommodative dysfunction
  - Home-based pencil pushups
  - Home-based computer vergence/accommodative therapy and pencil pushups
  - Office-based vergence/accommodative therapy with home reinforcement
  - BI prism readers

- Conclusion
  - Most effective was office-based vergence/accommodative therapy
  - Statistically different from office-based placebo therapy
  - Home-based remedies not as effective as office-based
  - Prism glasses did not treat symptoms/signs better than placebo

Convergence Insufficiency

**Signs**

- True CI (based on the Convergence Insufficiency Treatment Trial)
  1. Decreased NPC >6cm
  2. Exophoria at least 4pd greater at near than distance
  3. Decreased fusional convergence at near
- "Gross" CI
  - Reduced NPC

- Developmental CI is common in the general population ~ 2.5-13%

**Symptoms**

- Headache
- Eyestrain
- Double vision
- Blurry vision
- Loss of place while reading/words moving on the page
- Excessive redness when reading
- Closing an eye
- Short attention span for reading

Convergence Insufficiency Treatment Trial

- Most effective was office-based vergence/accommodative therapy
- Statistically different from office-based placebo therapy
- Home-based remedies not as effective as office-based
- Prism glasses did not treat symptoms/signs better than placebo

- Conclusion

Secondary Causes of CI

- Oculomotor Palsy/Restriction
  - CN IV
  - CN III
  - Duane Syndrome
- Neurological Disease
  - Pseudotumor cerebri
  - TBI/concussion
  - Behavioral medications
  - Parkinson’s Disease
  - Lyme Disease


NPC in Concussion

NPC after concussion in children

- N=275 pediatric patients aged 5-18 presenting to tertiary care children’s hospital subspecialty concussion program at Children’s Hospital of Philadelphia
- 67 (24%) had abnormal NPC
  - 26 (46%) recovered with standard clinical care over median of 4.5 weeks
  - 23 (41%) recovered a median of 11 weeks post injury after referral for formal vestibular therapy
  - 7 (13%) with persistent abnormal NPC necessitated referral for formal OVR, with recovery of 23 weeks post-injury, median of 16 weeks after referral to VT

NPC after SRC – relationship to neurocognitive impairment

- N=78 athletes, mean age 14 years
- Seen ~5 days after SRC and compared NPC to IMPACT and symptom assessments
- CI was common ~42%
- Patients with CI performed worse on:
  - Verbal memory
  - Visual motor speed
  - Reaction time
  - Symptom scores

Oculomotor Problems in TBI

Are we just finding pre-existing conditions we didn’t look for before?

- 100 post-concussion adolescents aged 11-17 years
  - 51% accommodative disorders
  - 49% convergence insufficiency
  - 29% saccadic dysfunction
  - 46% more than one of previously mentioned vision-related diagnoses

Vestibular-Ocular Reflex
Vestibular-Oculomotor
Visual Motion Sensitivity
and Eye Movements (Saccades/Pursuits)

Visual-Evoked Nausea

Visual Motion in Daily Life

Visual-Vestibular Motion in Sport
Higher Order Visual Processing

Object Processing
- Color
- Texture
- Pictorial detail
- Shape
- Size

Visual Attention and Visual Processing

Spatial Processing
- Location
- Movement
- Spatial transformations
- Spatial relations

Occupipal Lobe
Visual Cortex
- Color, Motion, Form

Visual Crowding (Simultanagnosia)

The monosyllabism who couldnt read very well,
She complained that the prints were blurry and moving,
She coudnt see the places on the page. She went to
her ophthalmologist who helped her ophthalmology is common
due to lesions of the occipital lobe. These problems can be
solved through vision therapy and sometimes improvement in
writing and most of how she saw the world. The vision therapy made a huge difference in her life.

Concussion Management

Current Approach to Tx
- No same day Return-to-Play (RTP)
- Need to be cleared by Physician for RTP
- Prescribed physical/cognitive rest until asymptomatic
- Accommodations at school/work
- Progressive symptom-based aerobic exertion-based RTP

Limitations
- Limited guidance on active treatment
- Limited evidence for effectiveness of prescribed rest
  - No randomized controlled trials
  - Lack of definition of “rest”
  - Recovery is influenced by severity of injury, type and timing of treatment

Wait – so Rest is Good…or is it??

Pros
- Rest decreases exposure to additional impacts
- Physical and cognitive activity exacerbate symptoms post-injury, prolonging recovery
- 1-week period of rest decreased Sx and increased cognitive scores in 60% of patients
  - Even when used several weeks/months after injury
- Initial brief rest may be beneficial

Cons
- You can avoid contact without avoiding all activity
- Physical and cognitive activity do not worsen pathophysiological injury or cause additional harm
- No association between prescribed rest and decrease or Sx or recovery time
- Patients with highest and lowest levels of activity had worse outcomes
  - Too little or too much rest may delay recovery
- What type, how long – still TBD
- Prolonged rest can lead to social isolation, anxiety, loss of academic/work standing


How Long Should Children Rest?

- No validated data demonstrating the appropriate duration of cognitive or physical rest in children with SRC.
- Thomas et al. RCT assessing post-SRC in 11-22yo - showed no significant difference in prescribed rest and those receiving usual care.
  - Those receiving strict rest reported more symptoms and longer symptom duration.
- Exercise at mild or self-selected levels does not appear to prolong symptoms and may shorten symptom duration and may be particularly beneficial for adolescent athletes (103)
- Rest in first few days may be beneficial, prolonged rest may delay recovery (both physical and cognitive rest).


Role for Vision Therapy?

- n=220 individuals with TBI (n=160) or CVA (n=60)
- Computer based query in clinical population
  - 2000-2003, selected those who completed optometric VT program TBI (n=160), CVA (n=60)
- Results: 90% with TBI and 100% with CVA had treatment success
  - Marked improvement in at least 1 primary symptom and at least 1 secondary sign
  - Improvements remained stable at retesting 2-3 months later


 TEAM Approach to Concussion - 2015

- Concussions are a treatable injury
  - More active/target approaches are better than prescribed rest alone
- Active Rehabilitation
  - Vestibular Therapy
  - Oculomotor/Vision Therapy
  - Behavioral Therapy

Post-Concussion Vision Exam

- Afferent Visual Pathway
  - Visual Acuity
  - Crowded/Isolated
  - VOR acuity (Dynamic Acuity)
- Confrontation VFs
- Eye movements
  - Fixation
  - Saccades
- Pupils
- VOR
- Number Reading Test (KD, DEM)
- Ocular Posture – Cover Test
- EOMs

Optometry’s Role?

- Pressing need for objective diagnostic tools for concussion assessment that are straightforward to administer
- Current research in using eye movements and oculomotor function for sensitive and objective biomarkers of cerebral dysfunction
- Can we track concussion with the visual system??
- Management of Post-Concussion/Head Injury Vision Problems

Optometric Management

Primary Care
- Vergence (Ranges, NPC, Facility)
- Accommodation (NPC, Facility)
- DEM
- Crowding (crowded acuity symbols)
- Rx
  - Focusing/vergence issues
  - Sunglasses
  - Reassurance

Tertiary Care - PCS
- Comprehensive Binocular Vision Assessment
- Visual Perceptual Skills Assessment
- Vision Therapy
- Vestibulo-Oculomotor Therapy

Active participation in multidisciplinary care!
Prescribed Accommodations/Advocacies

• Visual Motion Sensitivity/Visual Crowding
  – Removal from gym/dance class, band/orchestra, school assemblies
• Oculomotor Dysfunction
  – Delay tests/quizzes
  – Reduce amount of homework
  – Increase time on tests/assignments
  – Planned breaks
  – Note taker

• TEMPORARY MODIFICATIONS

Clinical Pearls

• The visual system is commonly affected in concussion
• The majority of visual problems self-resolve after concussion in 3-4 weeks, but some patients may need active therapy for full recovery
• Optometry has a role in the multidisciplinary management of concussion
• When in doubt refer to a colleague!

Thank you! Questions?

References

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