The Neuro-Ophthalmology Of Concussion:
The Evaluation and Management of Vision and Visual-Motor Abnormalities

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Associate Professor

Lecture Goals

- Geared toward the primary care optometrist
- Will review:
  - presentation of concussion
  - Important facts to know for well rounded care
- Determine optometric testing sequence and intervention options

Definitions

- **Traumatic Brain Injury (TBI)** - results from acute impact to the head causing brain dysfunction

- **Concussion** - a form of mild traumatic brain injury (TBI) owing to structural, metabolic and functional changes involving white matter tracts of the central nervous system in the absence of macroscopic findings

 Definitions

"During the past 7 years the practice has been too prevalent of allowing players to continue playing after a concussion. Again this year this is true. Sports demanding personal contact should be avoided after a concussion."

1937 – Proceedings of the 17th Annual Football Coaches Association

“The Concussion Epidemic”

- Increased NFL interest in concussion / chronic traumatic encephalopathy
- School sports/youth concussions drawing national attention
- Historical lack of evidence-based clinical protocols

1937 – Proceedings of the 17th Annual Football Coaches Association
**Statistics**

From The Concussion Legacy Foundation

- CDC estimates 3.8 million concussions each year
- Only 1 in 6 concussions are diagnosed
- 91 of 95 former professional football players have been diagnosed with CTE at the VA-BU-CLF Brain Bank

**Concussion Legacy Foundation Mission**

The Concussion Legacy Foundation (formerly the Sports Legacy Institute) is dedicated to advancing the study, treatment and prevention of the effects of brain trauma in athletes and other at-risk groups.

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**Concussion Facts**

- Functional rather than structural injury
- Axonal predilection – Diffuse axonal injury
- Loss of consciousness in less than 10%

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**What does the primary care practitioner need to know?**

**Concussion**

- Significant short and long term issues
- Early diagnosis and treatment are key to recovery
- Visual symptoms and signs are common during and post recovery

**MTX**
- Balance
- Cognition
- Vision
- Vision involves ½ of the brain’s systems
- Many of the areas of the brain housing visual systems are susceptible to impact

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**Concussion Epidemiology**

- 300,000 to 4 million per year
- Nearly 85% of concussions may go undiagnosed
  - Multiple studies suggest rate on rise
- Sports most affected
  - Boys’ High school football
  - Followed by girls’ soccer
- Girls have a higher rate of concussion

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**Concussion Tool Box: The Role of Vision in the Assessment of Concussion**


Concussion can lead to subtle changes in brain function. Tests of the visual system probe higher cortical functioning and increase our sensitivity in detecting these changes.

- Accommodation
- Convergence
- Extraocular motility
- Stereo acuity
- Pursuits
- Saccades
- Vestibulo-ocular reflex
- Balance
- Cognition
- Vision
High School Concussions

(Per 100,000)

- Football: Between 60 and 76
- Girls’ soccer: Between 33 and 35
- Boys’ lacrosse: Between 30 and 46
- Girls’ lacrosse: Between 20 and 31
- Boys’ soccer: Between 17 and 19
- Boys’ wrestling: Between 17 and 23
- Girls’ basketball: Between 16 and 18
- Softball: Between 11 and 16
- Boys’ basketball: Between 11 and 21
- Girls’ field hockey: Between 10 and 24
- Cheerleading: 11
- Girls’ volleyball: Between 5 and 8
- Boys’ baseball: Between 4 and 6


Concussion in Youth Sports

Children are more susceptible to head injury than adults and require a longer period of recovery than adults


Age of First Exposure to Football and Later-Life Cognitive Impairment in Former NFL Players (DETECT study)

Analysis of cognitive function among 42 former NFL players based on age of first exposure (AFE) to tackle football

- AFE <12 years
  - associated with greater later-life cognitive impairment
  vs.
  - AFE >12 years
  - Repetitive head trauma during critical period of brain development may lead to later-life cognitive impairment


What happens to the brain with concussion?

Biomechanics of Concussion

…”Brain in a Box”

- Direct injury to brain at point of contact (coup)
- Injury opposite the point of impact (contre-coup)
- Rotational forces with shearing/stretching of axons
- “wash-over” effect (blast injuries)


Real Life Examples
Case #1
15 year old male

- Concussion 2 months prior
  - Jumped down stairs → fell backwards → hit head

- Seen by neurologist specializing in concussion
  - Constant headaches
  - Fatigue

- Visual symptoms
  - Difficulty focusing on things up close
  - Intermittent diplopia (horizontal) with near work
    - Clears immediately with blink
  - School has allowed him to d/c homework and tests

Case #2
15 year old female

- Concussion 2 months prior
  - Hit with softball under Left eye
  - Broken nose
  - Concussion
  - Whiplash

- Seen by neurologist specializing in concussion
  - Fatigue
  - Difficulty concentrating
  - Headaches (variable pattern)
  - Photophobia, worse with fluorescent lighting
  - Nausea throughout day

- Visual symptoms
  - Non specific
  - SCL wearer x 4 years

Complications of Concussion

- Second-impact syndrome (SIS)
- Postconcussion syndrome (PCS)
- Chronic traumatic encephalopathy (CTE)

Second-Impact Syndrome

Sustaining a second concussion before “recovery” from first concussion

- Majority in pediatric/adolescent populations (< 20 yrs.)
- Loss of cerebral autoregulation with enhancement of cerebrovascular congestion
  - Diffuse cerebral edema / transtentorial herniation
  - 90% mortality (within minutes to days!)

Diagnosis and Statistical Manual of Mental Disorders, Fourth Edition.

Hedges RL et al., Brum 2009

Postconcussion Syndrome

- 2-5% of all concussions
- > 1 month's duration of three or more of the following:
  - Fatigue
  - Disordered sleep
  - Irritability / aggressiveness
  - Anxiety / depression
  - Personality changes / apathy
  - Impaired attention / memory
  - Impaired eye tracking

CTE

Chronic Traumatic Encephalopathy

- CTE is a progressive degenerative brain disease found in athletes, military veterans, and others with a history of repetitive brain trauma. Brain trauma can cause a build-up of an abnormal type of a protein called tau, which slowly kills brain cells. Once started, these changes in the brain appear to continue to progress even after exposure to brain trauma has ended.
Historical Perspective of CTE

- Martland – “Punch drunk” (JAMA 1928)
- Millspaugh – “Dementia pugilistica” (US Naval Medical Bulletin 1937)
- Critchley – “Medical aspects of boxing particularly from a neurological standpoint” (Psychological Bulletin 1957)
- Corsellis – neuropathology of CTE among boxers (Psychological Medicine 1973)

Common Signs & Symptoms

- Photophobia
- Accommodative dysfunction
- Binocular Vision dysfunction (Convergence insufficiency)
- Saccadic dysfunction

Vision Problems Associated with Concussion

Photophobia

- Accommodative dysfunction
- Binocular Vision dysfunction (Convergence insufficiency)
- Saccadic dysfunction

Vision Problems Associated with Concussion

Photophobia

- Accommodative dysfunction
- Binocular Vision dysfunction (Convergence insufficiency)
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Photophobia

- Photophobia/Photosensitivity: an elevated sensitivity to light in the absence of ocular inflammation or infection
  - Reported in between 20-40% in those with TBI who are NOT visually-symptomatic
  - Reported in nearly 50% of those with TBI who ARE visually-symptomatic
- Types of photosensitivity may be:
  1) generalized to all types of lighting
  2) selective to fluorescent lighting

Photophobia Etiology

- What causes it?


Conclusions

The results of these four papers led Clafford’s research team to hypothesize that anomalous cortical or subcortical regulation of response to changes in illumination and visual-spatial patterns, possibly mediated by the dorsal visual pathway, may be contributing to the perception of photosensitivity in those with TBI.
Photophobia

- Chronic / persistent photophobia seen with post concussion syndrome

  - Post-concussion syndrome is a complex disorder in which various symptoms — such as headaches and dizziness — last for weeks and sometimes months after the injury that caused the concussion.

  - In most people, post-concussion syndrome symptoms occur within the first seven to 10 days and go away within three months, though they can persist for a year or more.

Vision Problems Associated with Concussion

- Photophobia
  - Accommodative dysfunction
  - Binocular Vision dysfunction (Convergence insufficiency)
  - Saccadic dysfunction

Photophobia Treatment in TBI Patients

- Tinted lenses
- Colored overlays
- Brimmed caps

Often a subjective determination
  - Research looking for a more systematic determination

Colorimetry
  - means of determining the precise hue resulting in reduced visual stress for the patient

Optometric Evaluation

- Contrast Sensitivity
- Scotopic Sensitivity
- Critical flicker frequency
- Coherent motion

Optometric Exam Sequence

- Cross-sectional study of 100 subjects post concussion (mean age = 14.5 yrs)
  - 66% with one or more binocular vision problems
    - Accommodative disorders (51%)
    - Convergence insufficiency (49%)
    - Saccadic dysfunction (29%)

  - Highest prevalence if within 1 month of concussion


Not a lot of new information here 😊
Four General Areas of Visual Function

- Accommodative System
- Vergence System
- Oculomotor System
- Ocular Alignment System
- Vestibular-Ocular Reflex System

A Visual Efficiency Testing "Handbook"

Binocular Vision Disorders

- **EXO Deviations**
  - Convergence Insufficiency
  - Basic exo deviations
  - Divergence Excess

- **ESO Deviations**
  - Convergence Excess
  - Basic eso deviations
  - Divergence Insufficiency

DUANE'S CLASSIFICATIONS

<table>
<thead>
<tr>
<th>EXO Deviations</th>
<th>N = near fixation distance / F = far fixation distance</th>
<th>AC/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergence Insufficiency</td>
<td>N&gt;F</td>
<td>Low</td>
</tr>
<tr>
<td>Basic EXO deviation</td>
<td>N&gt;F</td>
<td>Normal</td>
</tr>
<tr>
<td>Divergence Excess</td>
<td>F&gt;N</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
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</thead>
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<td>Convergence Excess</td>
<td>N&gt;F</td>
<td>High</td>
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<tr>
<td>Basic ESO deviation</td>
<td>N&gt;F</td>
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<td>F&gt;N</td>
<td>Low</td>
</tr>
</tbody>
</table>
**Clinical Vergence Disorders**
**Soft Binocular Vision Problems**
Scheiman/Wick

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**Phoria Norms**
Cover test and phoropter measurements

<table>
<thead>
<tr>
<th></th>
<th>Distance</th>
<th>Near</th>
</tr>
</thead>
<tbody>
<tr>
<td>ortho - 2</td>
<td>∆ exophoria</td>
<td>ortho - 6 ∆ exophoria</td>
</tr>
</tbody>
</table>

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**How to record Smooth Vergence Measurements**

**Blur / break / recovery**

- **Blur** – patient reports blur
  - Fusional vergence is used up
  - Accommodation adjusting to maintain fusion
  - Should not be noted when testing distance vergences

- **Break** – patient reports diplopia
  - Patient uses up all vergence sources
  - Measures total amount of fusional and accommodative vergence

- **Recovery** – patient reports fusion
  - Diplopia is eliminated
  - Point where patient can re-access vergence system to regain single vision/fusion
  - Image may still be blurry

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**Vergences**

**Prism Bar Vergences/Step Vergence ADULTS**

<table>
<thead>
<tr>
<th></th>
<th>Near</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base In</td>
<td>x/13/10</td>
<td>x/19/14</td>
</tr>
<tr>
<td>Base Out</td>
<td>x/19/10</td>
<td>x/7/4</td>
</tr>
<tr>
<td>Base Out</td>
<td>x/11/7</td>
<td></td>
</tr>
</tbody>
</table>

**Vergences**

**Prism Bar Vergences/Step Vergence CHILDREN**

<table>
<thead>
<tr>
<th></th>
<th>Near</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base In</td>
<td>x/12/7</td>
<td>None established</td>
</tr>
<tr>
<td>Base Out</td>
<td>x/23/16</td>
<td>None established</td>
</tr>
<tr>
<td>Base Out</td>
<td>None established</td>
<td>None established</td>
</tr>
</tbody>
</table>

---
Near Point of Convergence Testing

<table>
<thead>
<tr>
<th>NPC Near Point of Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
</tr>
<tr>
<td>Adults</td>
</tr>
<tr>
<td>Accommodative target</td>
</tr>
<tr>
<td>(break/recovery)</td>
</tr>
<tr>
<td>Red lens / transilluminator</td>
</tr>
<tr>
<td>(break/recovery)</td>
</tr>
</tbody>
</table>

Accommodative Disorders

- **Accommodative Insufficiency**
  - Insufficient amplitude of accommodation to afford clear imagery of a stimulus object at a specified distance, usually the normal or desired reading distance.

- **Accommodative Excess**
  - Accommodation in excess of the amount required for sharpest imagery of the stimulus object.

- **Accommodative Infacility** (inertia of accommodation)
  - Slow or difficult accommodative response to dioptric change in stimulus; especially sluggish accommodative response to changes in fixation distance.

Accommodative Testing

<table>
<thead>
<tr>
<th>Accommodative Testing</th>
<th>Normative Value</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push up/Pull away amplitudes</td>
<td>15-⅓ age +/- 2.00D</td>
<td></td>
</tr>
<tr>
<td>NRA</td>
<td>+2.00 D</td>
<td>+/- 0.50 D</td>
</tr>
<tr>
<td>PRA</td>
<td>-2.37D</td>
<td>+/- 1.00 D</td>
</tr>
<tr>
<td>Minus lens amplitudes</td>
<td>15-⅔ age – 2D</td>
<td></td>
</tr>
<tr>
<td>MEM (monocular estimation method)</td>
<td>+0.50 D</td>
<td>+/- 0.25 D</td>
</tr>
<tr>
<td>Fused X-cylinder</td>
<td>+0.50 D</td>
<td>+/- 0.25 D</td>
</tr>
</tbody>
</table>

- Note: for amplitudes always be aware of even a small difference between the 2 eyes that is repeatable.
- If this is backed up by symptoms there may be an accommodative problem.

Accommodative Facility Testing

<table>
<thead>
<tr>
<th>Accommodative Facility Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test type</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>Binocular</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Monocular</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Binocular Vision Disorder Summaries
### Convergence Insufficiency

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent blur</td>
<td>Moderate to high esophoria or intermittent exotropia at near</td>
</tr>
<tr>
<td>Intermittent diplopia</td>
<td>Reduced positive fusional vergence at near</td>
</tr>
<tr>
<td>Symptoms worse at end of day</td>
<td>Low AC/A ratio</td>
</tr>
<tr>
<td>Burning and tearing</td>
<td>Low NRA</td>
</tr>
<tr>
<td>Inability to sustain and concentrate</td>
<td>Low MEM</td>
</tr>
<tr>
<td>Words move on the page</td>
<td>Fails binocular accommodative facility testing with +2.00</td>
</tr>
<tr>
<td>Sleepiness when reading</td>
<td>Intermittent suppression at near</td>
</tr>
<tr>
<td>Decreased reading comprehension over time</td>
<td>Receded near point of convergence</td>
</tr>
<tr>
<td>Slow reading</td>
<td>Normal accommodative amplitudes</td>
</tr>
</tbody>
</table>

### Fusional Vergence Dysfunction

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthenopia and headaches</td>
<td>Orthophoria or a low degree of exo or esophoria at distance and near</td>
</tr>
<tr>
<td>Intermittent blur</td>
<td>Reduced positive fusional vergence</td>
</tr>
<tr>
<td>Symptoms worse at end of day</td>
<td>Normal AC/A</td>
</tr>
<tr>
<td>Burning and tearing</td>
<td>Low NRA and PRA</td>
</tr>
<tr>
<td>Inability to sustain and concentrate</td>
<td>Fails binocular accommodative facility testing with both plus and minus</td>
</tr>
<tr>
<td>Sleepiness when reading</td>
<td>Normal monocular accommodative facility</td>
</tr>
<tr>
<td>Decreased reading comprehension over time</td>
<td></td>
</tr>
<tr>
<td>Slow reading</td>
<td></td>
</tr>
</tbody>
</table>

### Convergence Excess

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthenopia and headaches</td>
<td>Significant exophoria at near</td>
</tr>
<tr>
<td>Intermittent blur</td>
<td>Reduced negative fusional vergence at near</td>
</tr>
<tr>
<td>Intermittent diplopia</td>
<td>High AC/A ratio</td>
</tr>
<tr>
<td>Symptoms worse at end of day</td>
<td>Low PRA</td>
</tr>
<tr>
<td>Burning and tearing</td>
<td>High MEM</td>
</tr>
<tr>
<td>Inability to sustain and concentrate</td>
<td>Fails binocular accommodative facility testing with -2.00</td>
</tr>
<tr>
<td>Sleepiness when reading</td>
<td></td>
</tr>
<tr>
<td>Decreased reading comprehension over time</td>
<td></td>
</tr>
</tbody>
</table>

### Accommodative Disorder Summaries

**Accommodative Insufficiency**

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
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<tbody>
<tr>
<td>Blurred vision at near</td>
<td>Low accommodative amplitudes</td>
</tr>
<tr>
<td>Discomfort and strain associated with near tasks</td>
<td>Low NRA</td>
</tr>
<tr>
<td>Fatigue associated with nearpoint tasks</td>
<td>High MEM</td>
</tr>
<tr>
<td>Symptoms worse at end of day</td>
<td>Fails monocular accommodative facility with minus lenses</td>
</tr>
<tr>
<td>Difficulty with attention and concentration with reading</td>
<td>BAR - Fails (-)</td>
</tr>
</tbody>
</table>

**Accommodative Excess**

<table>
<thead>
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<th>Symptoms</th>
<th>Signs</th>
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<td>Low NRA</td>
</tr>
<tr>
<td>Fatigue associated with nearpoint tasks</td>
<td>Low MEM</td>
</tr>
<tr>
<td>Intermittent blurred distance vision, worse after reading</td>
<td>Low MEM BAR - Fails (+)</td>
</tr>
<tr>
<td>Difficulty with attention and concentration with reading</td>
<td>Variable acuity findings</td>
</tr>
<tr>
<td></td>
<td>Variable retinoscopy and subjective findings</td>
</tr>
<tr>
<td></td>
<td>Low degree of A/R astigmatism</td>
</tr>
</tbody>
</table>
Accommodative Infacility

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
</tr>
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<tbody>
<tr>
<td>Discomfort and strain associated with near tasks</td>
<td>Normal accommodative amplitudes</td>
</tr>
<tr>
<td>Fatigue associated with nearpoint tasks</td>
<td>Low NRA/PRA</td>
</tr>
<tr>
<td>Blurred vision when changing fixation form one distance to another</td>
<td>Low MEM</td>
</tr>
<tr>
<td>Difficulty with attention and concentration with reading</td>
<td>Fails monocular accommodative facility with plus and minus</td>
</tr>
</tbody>
</table>

Optometric Exam Sequence

- Refraction
- Assessment of Accommodative Skills
  - Minus lens amplitudes
  - Flipper Facility as needed
- Assessment of Binocular Vision Status
  - Cover test – distance and near
  - Vergences – typically near, distance as needed
  - NPC – Near Point of Convergence
  - Vergence Facility
- Ocular Motility evaluation
  - King Devick Test
  - DEM – Developmental Eye Movement Test

Accommodative Disorders

- Alvarez et al. 2012: 24%
- Ciuffreda et al. 2007: 41%
- Stelmack et al. 2009: 47%
- General population: 6-9%

The Accommodative Neural Circuit

- The afferent limb of the circuit includes the
  - retina - the retinal ganglion axons in the optic nerve, chiasm and tract
  - lateral geniculate body - axons in the optic radiations
  - visual cortex
  - Visual association in the cortex determines if the image is "out-of-focus"

Accommodative Dysfunciton with TBI

- Alvarez et al. 2012: 24%
- Ciuffreda et al. 2007: 41%
- Stelmack et al. 2009: 47%
- General population: 6-9%

Recommended clinical evaluation for accommodative testing:
- Accommodative amplitude
- Accommodative lens flipper facility fatigue
- Stimulus AC/A ratio
- Horizontal near heterophoria
- NRA / PRA

We can simplify this...
Symptoms of Accommodative Problems

**Accommodative Insufficiency**
- Blurred vision at near
- Discomfort and strain associated with near tasks
- Fatigue associated with nearpoint tasks
- Symptoms worse at end of day
- Difficulty with attention and concentration with reading

Clinical Signs of Accommodative Problems

- Hyperopic Rx has benefits
  - May improve near symptoms
  - May not tolerate Rx at distance
- Retinoscopy reflex fluctuates
  - Often see A/R astigmatism
  - Myopia
  - Subjective > retinoscopy
- Variable acuity / may not achieve level expected as per findings

Optometric Findings in Accommodative Insufficiency

**Signs**
- Low accommodative amplitudes
- Low PRA
- High MEM
- Falls monocular accommodative facility with minus lenses
- BAR - Falls ( )

Visual Acuity “mushy”
- Reduced distance VA
- Reduced near VA

Areas of Accommodation to Measure

- Accommodative Amplitudes
  - Push-up / Pull-away amplitudes (Donder’s)
  - Minus Lens Amplitudes
- Accommodative Response
  - NRA/PRA
  - Monocular Estimation Method (MEM)
- Accommodative Facility
  - Flipper Facility with +/- 2 D lenses

Let’s keep it Simple

Minus Lens Amplitudes

- Measures “power” of the accommodative system

Must determine age norm

<table>
<thead>
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Note: For amplitudes always be aware of even a small difference between the 2 eyes that is repeatable. If this is backed up by symptoms there may be an accommodative problem.
Control Rx = +2.50 sphere

Minus Lens Amplitudes
- Control lenses
- Near PD / Phoropter converged / stand lamp
- Using nearpoint rod/ target at 16”
  - One line larger than patients near VA
  - Normed for 20/40
- Test monocularly
- Add minus lenses in 0.25 D increments to first sustained blur
  - Alternative end points
    - Target goes “in and out” of clarity
    - Target is too small to read
- To obtain the amplitude in diopters add 2.50 D for the 40 cm WD

Target for Minus lens Amplitudes

PRA Findings

Occlude OS to begin Minus Lens Amps......

Minus Lens Amps ...... add 0.25 click of minus until first sustained blur
**Minus Lens Amplitudes**

To obtain the amplitude in diopters:
- add 2.50 D for the 40 cm WD
- Baseline +2.50 D

- **OD** → -2.00
  
  \[4.50 + 2.50 = 7.00\text{D}\]

- **OS** → -2.50
  
  \[5.00 + 2.50 = 7.50\text{D}\]

**Accommodative Facility Testing**

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Population</th>
<th>Normative Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Binocular</strong></td>
<td>Children (7-12)</td>
<td>5.0 cpm</td>
</tr>
<tr>
<td></td>
<td>Adults</td>
<td>8.0 cpm</td>
</tr>
<tr>
<td><strong>Monocular</strong></td>
<td>Children 7-12</td>
<td>7.0 cpm</td>
</tr>
<tr>
<td></td>
<td>Adults</td>
<td>11-12 cpm</td>
</tr>
</tbody>
</table>
Accommodative Facility

Modified facility testing

20/40 letter / line of letters

+2.00 D OU compared to -2.00 D OU

Is there blur?
Is one side more difficult than the other?

Which side is more difficult in Accommodative Insufficiency?

Accommodative Testing

1) Minus Lens Amplitudes

2) Flipper Facility

+2.00 D OU compared to -2.00 D OU

3) Trial Frame Plus at near

Start with +1.00 – +1.25

Subjective response

4) Take Distance VA OU with Near Rx

Can patient tolerate the plus at distance

Single vision vs bifocal Rx
Case #2
15 year old female

- Concussion 2 months prior
  - Hit with softball under Left eye
- Broken nose
- Whiplash

- Seen by neurologist specializing in concussion
  - Fatigue
  - Difficulty concentrating
  - Headaches (variable pattern)
  - Photophobia, worse with fluorescent lighting
  - Nausea throughout day

- Visual symptoms
  - Non specific
  - SCL wearer x 4 years

Case findings

<table>
<thead>
<tr>
<th>Snellen VA sc</th>
<th>Distance OD</th>
<th>OD</th>
<th>OS</th>
<th>Near OD</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20/20</td>
<td>20/20</td>
<td>20/20</td>
<td>20/20</td>
<td>20/20</td>
</tr>
</tbody>
</table>

Pupils / CF / EOM: normal
Stereopsis: (+) Forms / 25 sec
Refraction: -3.50 sph -3.50 sph
Dilated exam: unremarkable

Case #1
15 year old male

Initial Findings

<table>
<thead>
<tr>
<th>Cover Test cc</th>
<th>Distance Ortho</th>
<th>Near 2 x</th>
<th>OS</th>
<th>Near 2 x</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Near Prism Bar
Vergences cc
Base In x/26/10 Base In x/26/10

- NPC: 6 cm/9 cm
- Minus Lens Amplitudes: 0.00 D OD and OS
- NRA/PRA: +2.25 / -1.25
- Flippers: Able to clear + 2.00 D and unable to clear - 2.00 D

- King Devick Test: Age appropriate findings
  No ocular motor deficits

Signs

- Low accommodative amplitudes
- Low PRA
- High MEM
- Fails monocular accommodative facility with minus lenses
- BAR - Fails (-)

Binocular Vision Disorders

- Accommodative Insufficiency
  - Progressive lens prescribed over soft contact lenses to alleviate asthenopia with near work
  - Will not address photophobia with indoor tinted lenses at this time
  - recommended brimmed hat
  - RTC 1 month
- One month follow up
  - Patient notes great improvement in visual symptoms with Rx
Convergence Insufficiency with TBI

- Alvarez et al. 2012: 23%
- Ciuffreda et al. 2007: 42%
- Brahmm et al. 2009: 46%

General population: 4-6%
Prism Bar Vergences Base IN

How to record Step Vergence Measurements
Base IN

Blur / break / recovery

x/20/12

Norm: NBI x/13/10

Prism Bar Vergences Base OUT

How to record Step Vergence Measurements
Base OUT

Blur / break / recovery

x/20/12

Norm: NBO x/19/14
### Clinical Vergence Disorders

**Soft Binocular Vision Problems**

Scheiman/Wick

#### Vergences

<table>
<thead>
<tr>
<th>Vergences</th>
<th>CHILDREN</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Prism Bar Vergences/Step Vergence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near</td>
<td>Base In</td>
<td>x/12/7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base Out</td>
<td>x/23/16</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>Base In</td>
<td>None established</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base Out</td>
<td>None established</td>
<td></td>
</tr>
</tbody>
</table>

### Near Point of Convergence Testing

**NPC**

<table>
<thead>
<tr>
<th>NPC Near Point of Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Adults</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

### NPC → TN

### NPC for Stamina / Sustainability

### Concussion Recovery as a Function of NPC

- Prospective analysis of concussion symptoms and NPC among 28 collegiate athletes with sport-related concussion
- Shortened (improved) NPC with resolution of symptoms

Analysis of 78 athletes s/p sports-related concussion (ave. 6 days)
- Assessment of NPC, neurocognitive function (ImPACT) & post-concussion symptoms score (PCSS)
- 42% of concussed athletes had CI
- Athletes with CI had worse neurocognitive impairment and higher symptom scores than did those with normal NPC


Case #1
15 year old male
- Concussion 2 months prior
  - Jumped down stairs → fell backwards → hit head
- Seen by neurologist specializing in concussion
  - Constant headaches
  - Fatigue
- Visual symptoms
  - Difficulty focusing on things up close
  - Intermittent diplopia (horizontal) with near work
    - Clears immediately with blink
- School has allowed him to d/c homework and tests

Case #1
15 year old male
- Snellen VA
  - Distance
    - OD 20/20 OS 20/20
  - Near
    - OD 20/20 OS 20/20
- Pupils / CF / EOM normal
- Stereopsis (+) Forms / 25 sec
- Refraction
  - Pl -0.50 x 005 +1.25
  - Pl -1.00 x 005 +1.25
- Dilated exam unremarkable

Case #1
15 year old male
- Accommodative Insufficiency and Convergence Insufficiency
  - Bifocal Rx prescribed to alleviate asthenopia with near work
    - Pl -0.50 x 005 +1.25
    - Pl -1.00 x 005 +1.25
  - Convergence insufficiency noted, will re-evaluate findings at follow up
    - Consider therapy at follow up
  - RTC 1 month

Binocular Vision Testing Summary
1) Cover test – Distance and Near
2) Stereopsis
3) Vergence Evaluation – Base IN and base OUT
4) NPC
5) Vergence Facility Testing
Vergence Facility

Vergence facility attempts to capture the ability of the fusional vergence system to respond rapidly and accurately to changing vergence demands over time.

**Purpose/Goal of testing:**
To determine the ability to make large rapid changes in fusional vergence

Can address typical binocular vision symptoms

And can aid diagnosis in the absence of reduced binocular vision signs

Excellent tool in symptomatic traumatic brain injury (TBI) patients

Findings significantly lower in the visually symptomatic post concussion group as compared to visually normal group

---

**Vergence Facility**

- 20/30 target
- Hold target in primary gaze at 40 cm
- Prism Flipper over ONE EYE
- 12BO/3BI used
- Instruct patient that target may appear double and to make it single quickly - say NOW when single vision is achieved
- Perform for 1 minute alternating BI / BO
  - Record the number of cycles per minute (cpm)
  - One cycle = clearing BO prism and BI prism
- Expected values
  - Vergence Facility using 12BO/3BI = 15cpm (Adult)
  - Failure = < 15 cpm

---

**Vergence Facility with Stereoscopic and Nonstereoscopic Targets**

Optometry and Vision Science Issue; Volume 91(5), May 2014, p 522–527

Momeni-Moghaddam, Hamed; Gross, David A.; Dehvari, Abubakr

The highest vergence facility was obtained with a nonstereo target and the lowest was obtained with a stereo-global target. High sensitivity with all three targets means that there are few false-negative results with them, and the high specificity is indicative of low false-positive results. Hence, the vergence facility predictive value would be high in diagnosing binocular symptomatic patients using a 3[DELTA]BI/12[DELTA]BO prism flipper at near and a response cutoff of about 10 cycles per minute or less.
Vergence Facility

In addition to providing valuable normative data, this study indicates that the vergence system nearly
remains a `zero point` at any distance and sheds further light on the results of dynamic convergence and
vergence stimulation on the accommodative-vergence system. The recommended near vergence facility test is
readily implemented, using a commonly available flip prism (3 delta BI/12 delta BO) and having a
clinical failure criterion that is easily recalled (15 cpm, sum of the BI and BO magnitudes).

Case #3

52 year old male firefighter

Stellen VA sc
Distance: OS OD
Near: OS OD
20/20 20/20
20/20 20/20

Pupils / CF / EOM
normal

Stereopsis
(-) Forms / 25 sec

Refraction
OD: -3.25 -1.00 x 90
OS: -3.25 -1.00 x 90

Dilated exam
unremarkable


Case findings

(1) Diplopia, photophagia, eye tracking difficulties, headache, diplopia, and balance issues. Subject was hit on the head 2 years prior.

Not on active duty, can drive, but does not want to drive.

Snellen VA sc
Distance: OS OD
Near: OS OD
20/20 20/20
20/20 20/20

Initial Findings

<table>
<thead>
<tr>
<th>Test</th>
<th>Distance</th>
<th>Near</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover test cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance Prism Bar Vergences cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base In</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/8/4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/4/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Prism Bar Vergences cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base In</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/10/4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0/2/unable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPC</td>
<td>18 cm/10 cm</td>
<td></td>
</tr>
<tr>
<td>Vergeance Facility</td>
<td>12BO/3BI: Forms/ Unable to clear BO</td>
<td>Norm = 15 cpm</td>
</tr>
</tbody>
</table>

Treatment

- Single Vision Rx
  - Distance Rx = 3 Δ BO
  - Near Rx = 4Δ BI

- Began Office Based Vergence Training

Binocular Vision Testing

1) Cover test – Distance and Near
2) Stereopsis
3) Vergeance Evaluation – Base IN and base OUT
4) NPC

Optional: Vergence Facility Testing

Oculomotor Disorders

Saccade and Pursuit Dysfunction
Prospective analysis of 36 PCS subjects vs. healthy controls
PCS associated with worsening of anti-saccades, self-paced saccades,
memory-guided sequences & smooth pursuits
Eye movement dysfunction showed higher correlation with symptom load
as compared to neuro-psych testing
Biological substrate for concussion-related symptoms

**King Devick Test**
**Rapid Number Naming**

- Test Card 1
- Test Card 2
- Test Card 3

Test of saccades, verbalization & recall
High levels of test-retest reliability
High levels of validity for concussion identification


**King Devick Test**
**Rapid Number Naming**

- High reliability
- Designed originally as a reading test for kids
  - Easy
  - Takes less than a minute
  - Anyone can do it!
- The athlete is asked to read three test cards with numbers as quickly as possible, and total time is the baseline or pre-season score.
- > ½ of the brain’s pathways go into vision and reading, we anticipated that athletes with concussion would take longer to read the cards compared to a pre-season or pre-competition baseline.
**ABOUT THE KING-DEVICK TEST**

"King-Devick Test: a tool for evaluation of saccade, consisting of a series of charts of numbers. The charts become progressively more difficult to read in a flowing manner because of increasingly more difficult spacing between the numbers. Both errors in reading and speed of reading are included in deriving a score."

- The eyes are part of the brain
- Eye movements involve a wide network of structures in the brain
- Eye movements relate closely to the functional integrity of an injured brain
- Impaired eye movements are an indicator of suboptimal brain function

**EXTENSIVE PRESS COVERAGE**

- "Rinkside Test Accurately Helps Detect Professional Ice Hockey Team’s Concussions in Minutes"
- "The test can pick up deficiencies occurring across a wide range of neurological geography"
- "Many concussed athletes have passed SCAT but failed the King-Devick test."
- "Concussed athletes have great difficulty processing the numbers and can take minutes to finish, if they don’t give up entirely" 

**King Devick Test**

- Rapid Number Naming

- Has been examined in a range of athletes at various ages, may be useful in ID of concussion
- Worsening of baseline K-D test at the time of the injury indicates a 5x greater risk of concussion
- Reliable when administered by trained personnel and lay person
- Sensitive (86%) and specific (90%) for the detection of concussion

**Vision testing is additive to the sideline assessment of sports-related concussion**

- University of Florida study of K-D test, SAC & BESS in the sideline assessment of concussion
- SAC - Standardized Assessment of Concussion
- BESS - Balance Error Scoring System
- N=217 athletes (men’s football, women’s soccer, and women’s lacrosse with 30 concussions)

**Standardized Assessment of Concussion (SAC)**

- The SAC takes approximately 5 minutes to administer and includes measures of:
  - Orientation (month, date, day of week, year, time)
  - Immediate Memory
  - Neurologic Screening
  - Loss of consciousness
  - Amnesia
  - Strength
  - Sensation
  - Coordination
  - Concentration
  - Exertional Maneuvers
  - Delayed Recall

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  - Coordination
  - Concentration
  - Exertional Maneuvers
  - Delayed Recall
The BESS is a portable, cost-effective and objective method of assessing static postural stability. Takes approximately 10 minutes to conduct.

- **Three Stances**
  - double leg stance
  - single leg stance
  - tandem stance

- **Two Surfaces**
  - firm (ground)
  - foam surface.

**Results**

- 52% of concussions detected with SAC
- 79% of concussion detected with K-D test
- 80% of concussion detected with BESS
- 95% of concussions detected with combination of K-D & BESS
- 100% of concussions detected with combination of K-D, SAC & BESS


**Beyond the Science...**

- **Team Up Against Concussion**
  - Team Up Against Concussions is a free 30 minute concussion education program for schools, community centers, and athletic programs
  - Trained volunteers educate student-athletes about concussions through discussion, video, and interactive games, teaching them that successful athletes play hard and play smart. Using an evidence-based bystander intervention model, the program focuses on empowering student-athletes with the knowledge they need to take concussions seriously and foster a safer concussion culture
  - Aimed at grades 4-12

https://www.youtube.com/watch?v=Efpnm158y64

**King Devick Test**

- **Rapid Number Naming**

<table>
<thead>
<tr>
<th>Test Card 1</th>
<th>Test Card 2</th>
<th>Test Card 3</th>
</tr>
</thead>
</table>

- Test of saccades, verbalization & recall
- High levels of test-retest reliability
- High levels of validity for concussion identification


**Treatment of Oculomotor Disorders**

- **In office Vision Therapy**

  **King-Devick Recovery Acceleration Program**
K-D Test Pro Monitoring is a post-injury evaluation tool used to monitor the patient's oculomotor function during the concussion recovery process following identification of concussive injury. K-D Test Pro Monitoring may be used when a pre-injury K-D Test baseline is not available. The program uses charts and graphs to display K-D Test scores over the course of recovery.

- For clinical use only
- Standard-sized iPad App
- Quick, objective patient progress monitoring
- For serial post-injury testing
- Unlimited testing per patient for one year
- Purchase patient activations as needed
  - $20/patient
  - Minimal initial set-up required

For clinical use only
Standard-sized iPad App
Quick, objective patient progress monitoring
For serial post-injury testing
Unlimited testing per patient for one year
Purchase patient activations as needed
  - $20/patient
  - Minimal initial set-up required

Concussions: Rehabilitation

King-Devick Recovery Acceleration Program is a computer and tablet based oculomotor rehabilitation program for patients suffering from persistent symptoms.
- For clinical or home use
- Standard-sized iPad or laptop computer
- Requires Wi-Fi/internet
- Corrects deficits in eye movements and alleviates symptoms for many who have suffered a concussion
- Set goals and tailor programs for individual patients
- Real-time outcome measures to determine patient compliance and progress
- Patient has access to program for one year
- Patient activation costs - $65/patient; 10 code minimum
- Resell code to patients – SRP $90

King-Devick Test
Rapid Number Naming

- $650 training package of 10 subjects activations ($65 unit cost)
- Retail $90 / subject
  - $125 when combined with office therapy
- Guidance, compliance, real time follow up
- Evidence based training protocol:
  - 20 minutes/day
  - 3 days/week
  - 6 weeks
  - Totals = 6 hours training
- www.kingdevicktest.com
  - More information about sideline concussion screening
  - KD Team assists with on-boarding, training and implementation
  - General pricing questions, seek out sales and account management

King-Devick Video Resources

King-Devick Concussion Screening Test iPad App Demonstration Video
King-Devick Test Research and Publications
Mayo Clinic: King-Devick Test Detects Concussions in Youth Athletes
King-Devick Test On The Today Show

Email Questions To: support@kingdevicktest.com or visit: www.kingdevicktest.com

Some of our Key Relationships

Some of our Key Relationships

Return to Play
8 to 90% odds
- 40% of concussions are resolved in 1 week
- 70% of concussions are resolved in 2 weeks
- 80% of concussions are resolved in 3 weeks
- 95% of concussions are resolved in 5 weeks

90% within 21 days (Guskiewicz et al. 2003)

80 to 90% odds in 1 to 4 weeks!

Risks of Premature Return to Play

- Risk of second impact syndrome
- Repeat impact before normalization of brain function
- “window of vulnerability”
- Chronic headaches
- Depression
- Long-term cognitive deficits
- Post-traumatic encephalopathy (CTE)

2013 NCAA survey of 789 athletic trainers and 111 team physicians (530 institutions)

- 64.4% pressure from athletes
- 53.7% pressure from coaches

Greater pressure if female clinicians or if under supervisory purview of athletic department

Graduated Return to Play Protocol
Over days... weeks... months...

<table>
<thead>
<tr>
<th>Rehabilitation Stage</th>
<th>Functional Exercise at Each Stage of Rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) No activity</td>
<td>Complete physical, cognitive rest</td>
</tr>
<tr>
<td>2) Light aerobic exercise</td>
<td>Walking, swimming, stationary bike</td>
</tr>
<tr>
<td>3) Sport-specific exercise</td>
<td>Running drills in soccer, skating drills in hockey, etc.</td>
</tr>
<tr>
<td>4) Noncontact drills</td>
<td>More complex training drills, may start resistance training</td>
</tr>
<tr>
<td>5) Full-contact practice</td>
<td>With medical clearance, participate in normal training activities</td>
</tr>
<tr>
<td>6) Return to play</td>
<td>Normal game play</td>
</tr>
</tbody>
</table>

Benefits of Strict Rest After Acute Concussion: A Randomized Controlled Trial

- 88 individuals (age 11-22 years) with ED presentation for acute concussion
- Initial neurocognitive and balance assessments with daily record of post-concussive symptoms
- Randomized to:
  - strict rest (5 days) vs.
  - 1-2 days rest followed by step-wise return to activity
- No difference between groups regarding NC/balance outcomes
- Increased symptoms among strict rest group

Return to Learn
Return to Learn

- Return to learn must precede return to play
- Return to school when symptoms are tolerable for 30-45 min
  - usually within 2-4 days of concussion
- Schools/teacher should make adjustments to incorporate 5-10 min. of rest/hour

The Optometrist’s Role....

A Vision exam geared to rule out....

- Photophobia
- Accommodative dysfunction
- Binocular Vision dysfunction
  - (Convergence insufficiency)
- Saccadic dysfunction

Treatment Approaches

- **Lenses**
  - **Plus for near**
    - Determine bifocal vs single vision option
  - **Prism**
    - When applicable for diplopia issues
    - Consider Fresnel if temporary condition
- **Orthoptic / Vision therapy**
  - Scientific basis for therapeutic value
  - Addition to traditional vestibular and cognitive rehabilitation

Convergence Insufficiency Treatment Options

- **Lenses**
  - Refractive Error as necessary
  - Optimize spectacle and/or contact lens Rx
- **Added Lenses**
  - Prism
- **Orthoptics / Vision Therapy**
  - generally requires 12-24 office visits
  - dependent upon age, motivation, compliance

Convergence Insufficiency Studies

Vision therapy / orthoptics was the only treatment that produced clinically significant improvements in the near point of convergence and positive fusional vergence. Half the patients (58%) were still symptomatic at the end of treatment, although their symptoms were significantly reduced. All three groups demonstrated statistically significant changes in symptoms with 42% in office based vision therapy/orthoptics, 31% in office based placebo vision therapy/orthoptics, and 20% in home based pencil push ups.

A randomized clinical trial of vision therapy/orthoptics versus pencil push-ups for the treatment of convergence insufficiency in young adults

Convergence Excess Treatment Options

- **Lenses**
  - Refractive Error as necessary
  - Optimize spectacle and/or contact lens Rx

- **Added Lenses**
  - Plus lenses
    - Lowest amount of plus to eliminate symptoms and normalize exam data
  - Prism
    - Rarely needed if high AC/A ratio

- **Orthoptics / Vision Therapy**
  - Generally requires 12-24 office visits
  - Dependent upon age, motivation, compliance

---

Vision Therapy for Convergence Excess

*Journal of American Optometric Association, 1997 Feb;68(2):81-6*

Gallaway M, Schieman M

Record review of 83 patients with CE

Vision therapy was successful in enhancing negative fusional vergence and eliminating symptoms in the vast majority of patients with convergence excess and should be considered an effective treatment for this condition.

84% of patients reported a total elimination of initial symptoms.
Common Optometric Findings in Concussion

- Accommodative Disorders
- Convergence Disorders
- Ocular Motility Dysfunction

Concussion Response

- **Recognize**
  - When in doubt, sit them out
  - Concussions present with unique symptoms
  - If a concussion is suspected immediately remove the athlete from play.
  - Athletes must not return to play the same day it is confirmed or suspected they are suffering from a concussion

- **Consult**
  - It is critical the athlete is evaluated by a medical professional experienced with managing concussions as soon as possible after the injury occurs.

- **Recover**
  - Return to play protocol to gradually reintroduce the athlete to activity

- **Encourage**
  - Recovery can be a long and frustrating process
  - When it comes to concussion recovery, toughness means sticking to the recovery plan and not rushing back into play

Questions ??...... Thank You

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312-949-7279