Concussion Management

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Overview

• Prevalence
• Definition
• Pathophysiology of Concussion
• Identification/Diagnosis
• Acute Concussion Management
• Post-Concussion Syndrome
• Rehabilitation
• Prognosis
• Chronic Traumatic Encephalopathy (CTE)
Prevalence

• Sports = ~ 3.8 million/yr in USA → est. $56B
  – NHL – 7 yr study = 5.8% of players/season
  – New evidence suggests that it is MUCH higher

• MVA = ~ 240,000 (est. in USA)
  – mTBI occurs in 1 out of every 61 occupants in tow-away crashes –
    highest risk is rollovers (4.73+1.09%) and was reduced by 69.2% by
    seatbelt use (Viano et al., 2015)

• Workplace = est. 19.8 per 100,000 male workers

• War = 14.9% of soldiers returning from Iraq/Afghanistan

Langlois et al., 2006; Mihalik et al., 2005; Len et al., 2011; Laker, 2011
PREVALENCE OF CONCUSSIONS

Underreported

- 10-15% of athletes are estimated to experience concussions every year while playing contact sports.

- 5% of athletes experience concussions, according to trainers.

- 50% of athletes experience concussions, according to players.

Sports

With the highest concussion rates:

1. Football
2. Girl's Ice Hockey
3. Boy's Ice Hockey
4. Boy's and Girl's Rugby
5. Boy's Lacrosse
6. Girl's Soccer
7. Girl's Lacrosse
8. Boy's Soccer
9. Boy's Wrestling

(Castille et al., 2011; Daneshvar et al., 2011; Tommasone et al., 2006; CDC)

More Concussions

Occur during games than during practice.

Over 50% of concussions are never reported (Kay 2014)
Understanding Concussions

• Incidence vs. Reporting

• Prevention vs. Management

• Making the appropriate diagnosis and knowing when the individual has fully recovered is critical
What is a Concussion?

• “A traumatic brain injury induced by biomechanical forces”

• Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016
Old Theory

• Brain contacts the inside of the skull = bruising of the brain
What We Know Now

- Concussion = dysfunction in brain cells from a rapid acceleration/deceleration of the head
- Concussion = Mild traumatic brain injury (mTBI)
- NO physical/structural damage
  - no abnormality is seen on standard structural neuroimaging
# Brain Injury Classification

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasgow Coma Scale (GCS)</td>
<td>13-15</td>
<td>9-12</td>
<td>3-8</td>
</tr>
<tr>
<td>Post-Traumatic Amnesia (PTA)</td>
<td>&lt;24 hrs</td>
<td>24 hrs to 7 days</td>
<td>&gt;7 days</td>
</tr>
<tr>
<td>Loss of Consciousness</td>
<td>None - 30 mins</td>
<td>30 mins to 24 hrs</td>
<td>&gt;24 hrs</td>
</tr>
</tbody>
</table>
What We Know Now

- Pathophysiological process
- Stretching and shearing of neurons in the brain
  - Density difference between white and grey matter
  - Stretch/sheer occurs at interface between white and grey matter
- Results in an impaired ability of neurons to send and receive signals
Neuron Stretch/Shear
Pathophysiological Process

The Neurometabolic Cascade – Excitatory Phase

1. Stretch/Shear of Neurons (deformation of neuronal membrane)
2. Ion Imbalance (K\(^+\) out/Na\(^+\) in) = Neuron Depolarization
3. Massive Nerve Firing = Release of Neurotransmitters
4. Neurotransmitters (Glutamate) activate N-methyl-D-aspartate (NMDA) receptors = Influx of Ca\(^{2+}\)
Pathophysiological Process

The Neurometabolic Cascade – Spreading Depression

4. ATP Depletion = Energy Crisis

- ↑ demand for ATP by Na+-K+ pump
- Ca^{2+} uptake into mitochondria = ETC dysfunction = ↓ ATP production
- Rely on anaerobic metabolism (9x less efficient) and ↑ demand for glucose at time of ↓ blood flow
1. Depolarization/Action potential

2. Neurotransmitter release

3. Potassium efflux

4. Increased membrane pumping

5. Hyperglycolysis

6. Lactate accumulation

7. Calcium sequestration and mitochondrial dysfunction

8. Decreased energy (ATP) production

9. Enzyme activation and initiation of apoptosis

A. Calcium influx

B. Neurofilament compaction $\text{Ca}^{2+}$

C. Microtubule disassembly $\text{Ca}^{2+}$

D. Axonal swelling and secondary axotomy
Identification

Concussion

Fatigue

Dizzy

Vertigo

Nausea

Headache
When to Suspect a Concussion?

• Cause: direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head

• Result:
  – rapid onset of short-lived neurological impairments
  – in some cases, signs and symptoms evolve over a number of minutes to hours
  – may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury
  – range of clinical signs and symptoms that may or may not involve loss of consciousness

McCrory et al., 2017
Recognition – Signs & Symptoms

- Headache (94.3%)
- Nausea or vomiting
- Balance problems
- Dizziness (75.5%)
- Lightheadedness
- Fatigue
- Changes in sleep pattern
- Drowsiness
- Sensitivity to light (34%)
- Sensitivity to noise
- Vision problems
- Feeling not right or slowed down
- Difficulty concentrating (53.9%)
- Difficulty remembering
- Confusion (44%)
- Feeling of fogginess
- Irritability
- Sadness
- Nervous or anxious
- Feeling more emotional
- Neck Pain
- Numbness or tingling

Remove from work and play!
CONCUSSION RECOGNITION TOOL 5 ©
To help identify concussion in children, adolescents and adults

RECOGNISE & REMOVE
Head impacts can be associated with serious and potentially fatal brain injuries. The Concussion Recognition Tool 5 (CRT5) is to be used for the identification of suspected concussion. It is not designed to diagnose concussion.

STEP 1: RED FLAGS — CALL AN AMBULANCE
If there is concern after an injury including whether ANY of the following signs are observed or complaints are reported then the player should be safely and immediately removed from play/game/activity. If no licensed healthcare professional is available, call an ambulance for urgent medical assessment:

- Neck pain or tenderness
- Double vision
- Weakness or tingling/burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

Remember:
- In all cases, the basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Assessment for a spinal cord injury is critical.
- Do not attempt to move the player (other than required for airway support) unless trained to do so.
- Do not remove a helmet or any other equipment unless trained to do so safely.

If there are no Red Flags, identification of possible concussion should proceed to the following steps:

STEP 2: OBSERVABLE SIGNS
Visual clues that suggest possible concussion include:

- Lying motionless on the playing surface
- Slow to get up after a direct or indirect hit to the head
- Disorientation or confusion, or an inability to respond appropriately to questions
- Blank or vacant look
- Balance, gait difficulties, motor incoordination, stumbling, slow laboured movements
- Facial injury after head trauma

STEP 3: SYMPTOMS
- Headache
- "Pressure in head"
- Balance problems
- Nausea or vomiting
- Drowsiness
- Dizziness
- Blurred vision
- Sensitivity to light
- Sensitivity to noise
- Fatigue or low energy
- "Don't feel right"
- More emotional
- More Irritable
- Sadness
- Nervous or anxious
- Neck Pain
- Difficulty concentrating
- Difficulty remembering
- Feeling slowed down
- Feeling like "in a fog"

STEP 4: MEMORY ASSESSMENT
(IN ATHLETES OLDER THAN 12 YEARS)
Failure to answer any of these questions (modified appropriately for each sport) correctly may suggest a concussion:

- "What venue are we at today?"
- "Which half is it now?"
- "Who scored last in this game?"
- "What team did you play last week/game?"
- "Did your team win the last game?"

Athletes with suspected concussion should:
- Not be left alone initially (at least for the first 1-2 hours).
- Not drink alcohol.
- Not use recreational/prescription drugs.
- Not be sent home by themselves. They need to be with a responsible adult.
- Not drive a motor vehicle until cleared to do so by a healthcare professional.

The CRT5 may be freely copied in its current form for distribution to individuals, teams, groups and organisations. Any revision and any reproduction in a digital form requires approval by the Concussion in Sport Group. It should not be altered in any way, rebranded or sold for commercial gain.

ANY ATHLETE WITH A SUSPECTED CONCUSSION SHOULD BE IMMEDIATELY REMOVED FROM PRACTICE OR PLAY AND SHOULD NOT RETURN TO ACTIVITY UNTIL ASSESSED MEDICALLY, EVEN IF THE SYMPTOMS RESOLVE
Sideline Assessment

SCAT5®
SPORT CONCUSSION ASSESSMENT TOOL — 5TH EDITION
DEVELOPED BY THE CONCUSSION IN SPORT GROUP
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

Child SCAT5®
SPORT CONCUSSION ASSESSMENT TOOL
FOR CHILDREN AGES 5 TO 12 YEARS
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by
Concussion Examination

• History of the injury
  – Mechanism, symptoms (immediate & delayed)

• Rule out more sinister pathology
  – Red Flags
  – Canadian C-Spine Rules
  – Canadian CT Head Rules
  – Cranial Nerve exam
  – Cerebellar exam
  – Upper & Lower Limb Neurological Assessment
Red Flags

- Deteriorating conscious state (increasingly drowsy, can’t be woken up)
- Constant severe or worsening headache
- Repeated vomiting
- Inability to remember new events (asking the same questions repeatedly)
- Increasing confusion or irritability
- Strange behavior / unusual behavioral changes
- Seizures / convulsions
- Weakness, tingling, or burning in the arms or legs
- Unsteady on feet, loss of balance, slurring of speech, difficulty walking
- Double / blurry vision
- Fluid leaking from ears, bruising behind the ears, 2 black eyes
- Increasing neck pain or tenderness
- Progressive, worsening symptoms or new neurological symptoms

McCrory et al., 2017
Canadian C-Spine Rule

For alert (GCS=15) and stable trauma patients where cervical spine injury is a concern,

1. Any High-Risk Factor Which Mandates Radiography?
   - Age ≥ 65 years
   - Dangerous mechanism*
   - Paresthesias in extremities

   Rule Not Applicable If:
   - Non-trauma cases
   - GCS < 15
   - Unstable vital signs
   - Age < 16 years
   - Acute paralysis
   - Known vertebral disease
   - Previous C-spine surgery

   No

2. Any Low-Risk Factor Which Allows Safe Assessment of Range of Motion?
   - Simple rearend MVC**
   - Sitting position in ED
   - Ambulatory at any time
   - Delayed onset of neck pain***
   - Absence of midline c-spine tenderness

   No

   Radiography

   Yes

   Unable

3. Able to Actively Rotate Neck?
   - 45° left and right

   No Radiography

   Able

* Dangerous Mechanism:
  - Fall from elevation ≥ 3 feet / 5 stairs
  - Axial load to head, e.g., diving
  - MVC high speed (>100km/hr), rollover, ejection
  - Motorized recreational vehicles
  - Bicycle struck or collision

** Simple Rearend MVC Excludes:
  - Pushed into oncoming traffic
  - Hit by bus / large truck
  - Rollover
  - Hit by high speed vehicle

*** Delayed:
  - I.e. not immediate onset of neck pain
**Canadian CT Head Rule**

CT head is only required for minor head injury patients with any one of these findings:

<table>
<thead>
<tr>
<th>High Risk (for Neurological Intervention)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GCS score (&lt; 15) at 2 hrs after injury</td>
</tr>
<tr>
<td>2. Suspected open or depressed skull fracture</td>
</tr>
<tr>
<td>3. Any sign of basal skull fracture*</td>
</tr>
<tr>
<td>4. Vomiting (\geq 2) episodes</td>
</tr>
<tr>
<td>5. Age (\geq 65) years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medium Risk (for Brain Injury on CT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Amnesia before impact (\geq 30) min</td>
</tr>
<tr>
<td>7. Dangerous mechanism ** (pedestrian, occupant ejected, fall from elevation)</td>
</tr>
</tbody>
</table>

*Signs of Basal Skull Fracture
- hemotympanum, 'racoon' eyes, CSF otorrhea/rhinorrhea, Battle’s sign

**Dangerous Mechanism
- pedestrian struck by vehicle
- occupant ejected from motor vehicle
- fall from elevation \(\geq 3\) feet or 5 stairs

Rule Not Applicable If:
- Non-trauma cases
- GCS \(< 13\)
- Age \(< 16\) years
- Coumadin or bleeding disorder
- Obvious open skull fracture

Diagnosis

- Concussion
- Fatigue
- Nausea
- Dizziness
- Headache
- Difficulties
- Thinking
- Memory
- Sensitivity to light
- Sensitivity to noise
- Reduced coordination
- Vomiting
- Vertigo
- Dizziness
- Impaired balance
- Mood changes
- Changes in sleep
- Loss of balance
- Difficulty with concentration
- Rest
- Hockey
- Soccer
Concussion Diagnosis

• Any concussion-like symptoms following a significant impact = concussion (until proven otherwise)

• A concussion can only be diagnosed by a healthcare practitioner.

• Ideally, this professional will have specific training and experience in the assessment and management of concussions.

• Team approach
Differential Diagnosis

- The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc.) or other comorbidities (e.g., psychological factors or coexisting medical conditions).
Acute Concussion Management
Acute Concussion Management

• EDUCATE!!
  – Initial monitoring
  – Pathophysiology - NO PHYSICAL DAMAGE TO BRAIN
  – Return to learn
  – Return to play
Initial Monitoring

- Individuals should be monitored closely for at least 2-3 hours following suspected concussion due to the risk of developing serious complications.

- Warning Signs:
  - Deteriorating conscious state (increasingly drowsy, can’t be woken up)
  - Constant severe or worsening headache
  - Repeated vomiting
  - Inability to remember new events (asking the same questions repeatedly)
  - Increasing confusion or irritability
  - Strange behavior / unusual behavioral changes
  - Seizures / convulsions
  - Weakness, tingling, or burning in the arms or legs
  - Unsteady on feet, loss of balance, slurring of speech, difficulty walking
  - Double / blurry vision
  - Fluid leaking from ears, bruising behind the ears, 2 black eyes
  - Increasing neck pain
  - Progressive, worsening symptoms or new neurological symptoms
First 24-48 Hours

- Continue to monitor for warning signs
- If concerned that the individual is not stable, wake every 2 hours briefly
- Pain medications/alcohol/drugs should be avoided – can mask the signs of a worsening condition
- Relative physical and cognitive rest
  - Absolute rest is no longer the best approach!
  - 2-3 days of rest is max, then start pushing back into cognitive & physical activity that doesn’t provoke symptoms
- Follow up with a health care practitioner

McCrory et al., 2017
## Acute Concussion Management

### Return to Learn (Work)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Daily activities at home that do not give the child symptoms</td>
<td>Typical activities of the child during the day as long as they do not increase symptoms (eg, reading, texting, screen time). Start with 5–15 min at a time and gradually build up</td>
<td>Gradual return to typical activities</td>
</tr>
<tr>
<td>2</td>
<td>School activities</td>
<td>Homework, reading or other cognitive activities outside of the classroom</td>
<td>Increase tolerance to cognitive work</td>
</tr>
<tr>
<td>3</td>
<td>Return to school part-time</td>
<td>Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day</td>
<td>Increase academic activities</td>
</tr>
<tr>
<td>4</td>
<td>Return to school full time</td>
<td>Gradually progress school activities until a full day can be tolerated</td>
<td>Return to full academic activities and catch up on missed work</td>
</tr>
</tbody>
</table>
Acute Concussion Management

Return to Play

Table 1  Graduated return-to-sport (RTS) strategy

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Symptom-limited activity</td>
<td>Daily activities that do not provoke symptoms</td>
<td>Gradual reintroduction of work/school activities</td>
</tr>
<tr>
<td>2</td>
<td>Light aerobic exercise</td>
<td>Walking or stationary cycling at slow to medium pace. No resistance training</td>
<td>Increase heart rate</td>
</tr>
<tr>
<td>3</td>
<td>Sport-specific exercise</td>
<td>Running or skating drills. No head impact activities</td>
<td>Add movement</td>
</tr>
<tr>
<td>4</td>
<td>Non-contact training drills</td>
<td>Harder training drills, eg, passing drills. May start progressive resistance training</td>
<td>Exercise, coordination and increased thinking</td>
</tr>
<tr>
<td>5</td>
<td>Full contact practice</td>
<td>Following medical clearance, participate in normal training activities</td>
<td>Restore confidence and assess functional skills by coaching staff</td>
</tr>
<tr>
<td>6</td>
<td>Return to sport</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: An initial period of 24–48 hours of both relative physical rest and cognitive rest is recommended before beginning the RTS progression. There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen during exercise, the athlete should go back to the previous step. Resistance training should be added only in the later stages (stage 3 or 4 at the earliest). If symptoms are persistent (eg, more than 10–14 days in adults or more than 1 month in children), the athlete should be referred to a healthcare professional who is an expert in the management of concussion.

Update: REMOVAL OF ABSOLUTE REST!
"Children and adolescents should not return to sport until they have successfully returned to school..." – Davis et al., 2017
RECOVERY STAGES OF CONCUSSION

Concussed individuals should remain in each of the following stages for at least 24 hours. You must not be experiencing any symptoms prior to attempting the next stage.

1. **REST**
   - Monitored by the PARENTS
   - Stimulation can burn depleted energy and cause longer recovery. Avoid technology, intense exercise and bed rest. Go for a light walk and do things around the house.

2. **LIGHT MENTAL ACTIVITY AT HOME**
   - Monitored by the PARENTS
   - Should be symptom free at rest for 24 hours. Try light cognitive activity for up to 45 minutes, like watching TV, reading or homework.

3. **HALF DAY OF SCHOOL OR WORK**
   - Monitored by the SCHOOL TEACHER
   - Get used to class and crowds, but no tests, homework, gym, recess, or music class. Avoid activities that put the head at risk.

4. **FULL DAY OF SCHOOL**
   - Monitored by the SCHOOL TEACHER
   - The same light school activities for a full day.

5. **LIGHT PHYSICAL ACTIVITY**
   - Monitored by the CCMI CLINICAN
   - Make an appointment for a Buffalo treadmill test at a CCMI facility. If you fail, you can try again in 2-3 days.

6. **LIGHT PRACTICE**
   - Monitored by the COACHES
   - Try returning to a sport environment. Perform light, sport-specific drills and see how you feel. If you experience symptoms, stop the practice.

7. **INTENSE NON-CONTACT PRACTICE**
   - Monitored by the COACHES
   - Try more intense non-contact drills. Increase the challenge and hart rate. If you experience symptoms, stop the practice.

8. **MEDICAL CLEARANCE**
   - Monitoried by the CCMI CLINICAN
   - NHL exertion test & re-testing of baseline parameters.

9. **FULL CONTACT PRACTICE**
   - Monitored by the COACHES
   - Play 1 full intensity practice prior to a full game. If there are no symptoms, you can play in a game.

10. **FULL RETURN TO PLAY**
    - Monitored by the COACHES
    - Full return to competition.

If symptoms are experienced at any stage, drop back to the previous stage for at least 24 hours. You must be asymptomatic prior to attempting the next stage again.

CCMI App Legend
- Red: Player cannot participate
- Yellow: Practice with no contact
- Green: Uninjured with no restrictions

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Importance of Full Recovery

• The brain is extremely vulnerable during recovery:
  – Energy needs to be restored
  – Anything that uses energy delays recovery
  – A very minor impact can cause another concussion
  – 2\textsuperscript{nd} concussions are much more severe
    • ’Second Impact Syndrome’

• Nerves are dysfunctional:
  – Your systems are down
  – Processing speed is slowed
  – Balance is off
  – Reaction time is slowed
Recovery

• 90% of concussions will recover symptomatically within 7-10 days
• Symptom recovery does not correlate to physiological recovery
• CAUTION!
ATP time course after moderate TBI

ATP (umol/g w.w.)

Time

Sham  1 min  10 min  30 min  2 hrs  6 hrs  15 hrs  24 hrs  48 hrs  120 hrs

Signoretti et al., 2001
Vagnozzi et al., 2005

Recovery!
Vagnozzi et al., 2010

![Graph showing metabolite ratios over days after concussion](image)
## Vulnerability in Humans

<table>
<thead>
<tr>
<th>Sub</th>
<th>Age</th>
<th>Sex</th>
<th>Sport</th>
<th>Symptoms (after 1st)</th>
<th>Symp Duration</th>
<th>Time btw</th>
<th>Symptoms (after 2nd)</th>
<th>Symp Duration</th>
<th>NAA Norm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>M</td>
<td>Boxing</td>
<td>Headache, amnesia</td>
<td>3</td>
<td>10</td>
<td>LOC, HA, concentration probs, irritability, sleep probs</td>
<td>52</td>
<td>120d</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>M</td>
<td>Rugby</td>
<td>Headache, nausea, amnesia</td>
<td>4</td>
<td>9</td>
<td>LOC, HA, nausea, retrograde amnesia, irritability, sleep probs</td>
<td>59</td>
<td>120d</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>M</td>
<td>Soccer</td>
<td>HA, fatigue, nervousness</td>
<td>8</td>
<td>18</td>
<td>HA, Irritability, diff concentrating, foggy vision, nausea</td>
<td>44</td>
<td>90d</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>M</td>
<td>Soccer</td>
<td>HA, sleep probs</td>
<td>7</td>
<td>16</td>
<td>HA, nausea, sleep probs, dizziness</td>
<td>35</td>
<td>90d</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>M</td>
<td>Kickbox</td>
<td>HA, sleep probs</td>
<td>8</td>
<td>21</td>
<td>HA, retro, sleep, concentration</td>
<td>24</td>
<td>60d</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>M</td>
<td>Boxing</td>
<td>HA, Anterograde amnesia</td>
<td>5</td>
<td>19</td>
<td>HA, fatigue, dizzy, tingling, irritability</td>
<td>33</td>
<td>90d</td>
</tr>
</tbody>
</table>
Meehan et al., 2012

- Multiple injuries in mice at varying time points:
  - Group 1 – 1 concussion every month for 5 months
  - Group 2 – 1 concussion every week for 5 weeks
  - Group 3 – 1 concussion every day for 5 days
  - Control – anaesthetized but no impact was delivered

- Tested on Morris Water Maze (cognitive measure):
  - @ 1 month after final injury group 2 & 3 were significantly different than control – group 1 = no difference
  - @ 1 year - group 3 still showed significant cognitive impairment vs. control, group 2 ‘tended’ to show worse performance (but not significant), and group 1 showed no difference vs. uninjured control on MWM
When Has Someone Recovered?

• Symptoms = Unreliable
• Imaging? No
• Need objective measures!
  – Balance, cognitive processing, memory, visual processing, strength, reaction time, etc. (Pre-injury)
  – Used for RTP (not diagnosis)
  – NOTE: MULTIMODAL!
    • Computerized testing shows poor test-retest reliability when used as stand-alone
• Can’t use normative data
  – Range of normal is too broad
  – Have not established sufficient norms yet
Symptoms vs. Brain Recovery

- Symptoms: 7 – 10 Days
- Brain Recovery: 2 – 4 Weeks
Baseline Testing

“The Ontario Neurotrauma Foundation recommends considering baseline testing for children and adolescents who play high-risk sports. Additionally, the Centres for Disease Control and Prevention suggests baseline testing be repeated annually to establish a valid test result for comparison.”

-Holland-Bloorview Kids Rehabilitation Hospital
Baseline Testing

- Battery of tests
- Conducted annually
- Completed pre-season
- Used to guide safe decision making
- Ensure adequate recovery for safe RTP
Baseline Testing Components

Complete Concussion Management Protocol

• Symptom evaluation
• Orientation
• Memory
• Concentration
• Vision and visual processing speed
• Balance
• Postural sway
• Reaction time
• Motor strength
• ImPACT
Why is This Important?

- Rowan Stringer – 17 year old female rugby player
- 2013 – died after being tackled
- Doctors were unable to relieve cerebral swelling
- Reports came out that she had been hit 2 weeks and 1 week earlier and had been complaining of a headache
  - *Asymptomatic at the time*
Rowan’s Law

- To ensure athlete safety, this collaborative approach must extend outside of the health care team to all coaches, teachers, employers AND teammates.

- “It is the responsibility of the athlete or their parent/legal guardian to provide documentation of the athlete’s concussion to coaches, teachers or employers. It is also important for the athlete to provide this information to sport organization officials that are responsible for injury reporting and concussion surveillance, where applicable.”

  Canadian Guideline on Concussion in Sport
Post-Concussion Syndrome
Post-Concussion Syndrome

• Concussion recovery typically follows a sequential course, but in some cases symptoms may be prolonged.
• Dx criteria: ICD-10 and DSM-5 (1-3 months or greater = PCS)
  – ICD-10: concussions are considered to be PCS at 4 weeks after injury.
• Most common symptoms are HA, dizziness, concentration/memory difficulties
  – also anxiety, depression, visual problems.
Persistent Symptoms

Berlin expert consensus:

• “Use of the term ‘persistent symptoms’ following SRC should reflect failure of normal clinical recovery—that is, symptoms that persist beyond expected time frames (ie, >10–14 days in adults and >4 weeks in children)”

• “Persistent symptoms do not reflect a single pathophysiological entity, but describes a constellation of non-specific post-traumatic symptoms that may be linked to coexisting and/or confounding factors, which DO NOT NECESSARILY REFLECT ONGOING PHYSIOLOGICAL INJURY TO THE BRAIN”
Rehabilitation

• Concussion can result in diverse symptoms and problems, and can be associated with concurrent injury to the cervical spine and peripheral vestibular system

• The data support interventions including psychological, cervical, and vestibular rehabilitation

• In addition, closely monitored active rehabilitation programs involving controlled sub-symptom-threshold, submaximal exercise have been shown to be safe and may be of benefit in facilitating recovery

• A collaborative approach to treatment!
  – “Overall, these are difficult cases that should be managed in a multidisciplinary collaborative setting, by healthcare providers with experience in SRC.”
Rehabilitation

- Main causes of PCS:
  - Physiological
    - Decreased blood flow
    - Inflammation – cyclical
  - Cervicogenic
    - WAD
  - Vestibular and/or Visual
    - Dizziness
  - Psychological
    - Anxiety, depression
    - “Good ol’ days” bias
Rehabilitation

• Ax for blood flow abnormalities
  • HR monitored tolerance to activity test – supervised
  • Nutritional education

• Whiplash/Neck
  • Treated through Manual Therapy/Rehab

• Vestibular and/or Visual Issues
  • Vestibular and/or visual therapy

• Psychological
  • Education/Reassurance
  • Referral to psychologist/psychiatrist as needed

• All are treatable, and can begin management as early as 10 days – Can prevent PCS with early intervention!
Physiological - Exercise

- Physical rest/inactivity becomes detrimental to recovery
  - Physical aspects (deconditioning)
  - Psychosocial aspects (↑ anxiety & depression)
- Exercise
  - Up-regulates BDNF, improves mood, improves cerebral blood flow & O₂ delivery, provides sense of control
  - Must be done in a controlled manner (subsymptom threshold)

Leddy et al., 2007; 2011; Baker et al., 2012; Ellis et al., 2016
Physiological - Nutrition

• Reduce foods that promote inflammation:
  – Refined sugars and carbs
  – Alcohol

• Increase foods that support brain function/healing:
  – Fruits and vegetables (antioxidants)
  – Good fats (fish, flax seed, walnuts, olive oil)
  – Healthy spices (tumeric, ginger)
Cervical Spine

• Biomechanics
  – Concussion
    • Rotational and Linear Forces
      – Highest Predictive Occurrence – >96.1G Linear Acceleration
        >5,500 rad/s²
  – Whiplash studies
    • Cervical strain injury happens at >4.5G

• **Consider underlying c-spine injury/dysfunction (even without neck pain)**
mTBI
- Headache
- Dizziness/Balance Problems
- Cognitive Disturbance
- Memory/Concentration Impairment
- Visual Disturbance
- Fatigue
- Psychological Distress
- Nausea
- 12.6% have neck pain

WAD
- Neck Pain/Stiffness
- Headache
- Dizziness/Balance Problems
- Cognitive Disturbance
- Memory/Concentration Impairment
- Visual Disturbances
- Fatigue
- Psychological Distress
- Arm Pain & Paresthesia
- TMJ Dysfunction

Yadla et al, 2007; Haldorsen et al., 2003; Findling et al., 2011; Fazio et al., 2007; McCrory et al., 2008
“Sidney Crosby's latest concussion-related layoff may not be a concussion after all, but rather a more-treatable neck injury that went undiagnosed for weeks if not months. After meeting with specialists on both U.S. coasts during the last week, the Pittsburgh Penguins captain was told Tuesday he has a soft tissue injury that is causing swelling in his top two vertebrae.”

Additional Treatment: Medication

- There is no evidence of any medications helping with the recovery process following concussions
- Medications can mask the signs of worsening condition
- Potential to create rebound headaches
- Side-effects may mimic concussion-like symptoms
Prognosis
Predicting Recovery

• Persistent symptoms = >14 days (adults)
  – Without early intervention, roughly 30% will go on to have PCS

• Predictors for prolonged recovery
  – We cannot grade a concussion in the acute phase!!
  – Important points
    • LOC – no bearing on recovery – does not predict severity of injury
    • Repeated concussions may (especially when close together)
    • Children and adolescents (females recently)
    • Pre-existing depression/anxiety
    • Severity of initial symptoms
    • Lack of patient education following injury
      – ONF persistent symptoms guidelines
Predicting Recovery

• “The strongest and most consistent predictor of slower recovery from SRC is the severity of a person’s initial symptoms in the first day, or initial few days, after injury.”

• “.psychological factors play a significant role in symptom recovery and contribute to risk of persistent symptoms in some cases.”
  - Early visits to a HCP with training and expertise in concussion can help alleviate these symptoms through education and reassurance
Dashed = Typical recovery
Dotted = Uninjured Controls
Solid = Prolonged Recovery

Rabanowitz et al., 2015 found the same thing – symptom severity at acute presentation, being female, older age at injury were best predictors of prolonged recovery (>3 months) (LOC & PTA had no effect at all)
What is it?

• Progressive degeneration disease which afflicts the brain of people who have suffered repeated concussions and traumatic brain injuries.

• The brain of an individual who suffer from CTE gradually deteriorates and will over time end up losing mass.

• Certain areas of the brain are particularly liable to atrophy, though other areas are prone to becoming enlarged.

• Some areas of the brain experience an accumulations of TAU Protein, a substance which serves to stabilize cellular structure in the neurons but which may become defective and subsequently may cause major interference with the function of the neurons.

(Brain Injury Research Institute)
Chronic Traumatic Encephalopathy

Common Symptoms

1) Loss of memory
2) Difficulty controlling impulsive or erratic behavior
3) Impaired judgement
4) Behavioral disturbances including aggression and depression
5) Difficult with balance
6) Gradual onset of dementia.

(Brain Injury Research Institute)
A recent UCLA study appears to have opened the door to being able to diagnose CTE in living test subjects, by identifying concentrations of tau protein. With diagnostic tests which can identify the signs of early onset CTE, it would be possible to screen professional athlete, military personnel and others who are at risk for developing this condition so as to safeguard their future health and happiness.

(Brain Injury Research Institute)
Chronic Traumatic Encephalopathy

• Berlin:

"The literature on neurobehavioral sequelae and long-term consequences of exposure to recurrent head trauma is inconsistent. Clinicians need to be mindful of the potential for long-term problems such as cognitive impairment, depression, etc in the management of all athletes. However, there is much more to learn about the potential cause-and-effect relationships of repetitive head-impact exposure and concussions. The potential for developing chronic traumatic encephalopathy (CTE) must be a consideration, as this condition appears to represent a distinct tauopathy with an unknown incidence in athletic populations. A cause-and-effect relationship has not yet been demonstrated between CTE and SRCs or exposure to contact sports. As such, the notion that repeated concussion or subconcussive impacts cause CTE remains unknown."

McCrory et al., 2017
Chronic Traumatic Encephalopathy

Unanswered questions:

1) Frequency of presentation in collision sports
2) Relationship b/w concussion and CTE
3) How many concussions to get degeneration
4) Do sub concussive blows have same deficits and pathological changes as concussive
5) Is it specific to concussion
Take Home Messages

- MOI + ≥ 1 signs or symptoms = concussion
- Severity of concussion is retrospective
- When in doubt, sit them out/ Recognize and Remove
- Energy crisis problem
- Think rest for 24-48 hours max, then shift focus to recovery
- Concussions are treatable injuries
- Proper management is critical
Questions?
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