Neuropsychological Management of Pediatric Concussion

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Disclosures

• The content of this presentation does not relate to any product of a commercial entity; therefore, I have no relationships to report.
Goals and Objectives

- Review postconcussion symptoms following pediatric mild TBI and concussion
  - focus on cognitive and emotional
- Current issues in assessment of cognitive and emotional factors of concussion
- Discuss management of concussion
  - Particular discussion on cognitive rest
  - Proposed model for management
What’s in a name?

• Confusion in terms:
  • Minor closed head injury
  • Mild closed head injury
  • Mild traumatic brain injury
  • Concussion
  • Sport related concussion

• Mild traumatic brain injury occurs on a spectrum

- Mild “sport related” concussion
  - Injury: sport related
  - GCS=15, LOC-none
  - CT/MRI negative

- Complicated mild TBI
  - Injury: motor vehicle collision
  - GCS=13, LOC of 15 minutes
  - MRI=Diffuse Axonal Injury
Impact of Mild TBI/Concussion
Post Concussion Symptoms

• Barlow et al. (2010)
  • (n=670 TBI; n=197 other injury)
  • Groups equal in retrospective ratings of premorbid concussive symptoms
  • More postconcussive symptoms for TBI group at both 1 month and 3 months
  • Greatest changes relative to premorbid ratings
    • Fatigue (79%)
    • “More emotional” (60%)
    • Irritability (58%)
    • Headaches (58%)
  • 9% of all children with mTBI met ICD-10 criteria for Postconcussion Syndrome (PCS)
Emotional Psychiatric Concerns

• Emery et al., 2016 most commonly studied problems following mTBI include:
  • Attention deficit/hyperactivity disorder (ADHD) symptoms
  • Oppositional defiant/conduct disorder
  • Depression
  • Anxiety

• Luis & Mittenberg, 2002 mTBI (n=42)
  • 35% novel anxiety disorder
  • 21% novel mood disorder
    • Injury severity moderated relationship

• Max et al., 2012 mTBI
  • 11% showed novel depression
  • Injury severity/neuroimaging findings seemed related to depressive symptoms
Neurocognitive Functioning

- Meta-analysis generally suggest positive recovery of cognitive function following mTBI. Babikian & Arsanow, 2009 (28 publications of pediatric TBI)

- Significant differences were noted in:
  - Immediate verbal memory (more apparent in post-acute studies)
  - Processing speed (lingering problem)
Neurocognitive Functioning (Sport Related Concussion)

• Belanger & Vanderploeg (2005)
  • Meta analysis of 21 studies, (n = 790 sport related concussion cases)
  • Acute deficits:
    • Memory acquisition & recall
    • Attention
    • Executive Functions
    • Visual spatial
    • Fine motor
  • Group differences do not persist beyond 10 days
Yea but . . .

- Rare examples of cognitive dysfunction may be difficult to detect in mean group data
- Even if cases with persistent cognitive difficulties represent a small fraction of concussion, this represents a significant concern given the prevalence of the concussion
- Most studies exclude patients with prior concussion
  - Belanger & Vanderploeg (2005) greater difficulties in studies that included repeat injury
- Leads to a selective population “miserable minority” in concussion clinics receiving evaluation
The Paradox

• Little evidence for long term cognitive changes in the vast majority of cases of sport related concussion

• However . . .
  • Evidence that return to sport while concussed may place an athlete at risk for second injury
  • Evidence that repeat concussion while still recovering from a prior injury leads to particular risk for PCS
    • Second impact syndrome?
  • Many school athletes underreport symptoms following first concussion
    • McCrea et al. (2005)
      • 635 concussions in high-school and college
      • 40% of players indicated that they returned to play while symptomatic from concussion
What about a Biomarker?
Prevalence of Abnormal Magnetic Resonance Imaging Findings in Children with Persistent Symptoms after Pediatric Sports-Related Concussion

Robert H. Bonow,1,2 Seth D. Friedman,3 Francisco A. Perez,1 Richard G. Ellenbogen,2 Samuel R. Browd,2 Christine L. Mac Donald,2 Monica S. Vavilala,1,5 and Frederick P. Rivara1,6

• Children/adolescents with sport related concussion
• Excluded patients with positive CT imaging (e.g. skull fracture, pneumocephalus, subarachnoid hemorrhage)
• n=427 underwent MRI
• 63 (15.7%) had abnormal MRI unrelated to concussion (most common Pineal cyst or Chiari-1)
• Only 2 (0.46%) had findings thought to be related to concussion
  • Petechial micro hemorrhage
    • Both patients experienced 3 prior concussions (group median was 0)
    • Mechanisms: helmeted head to head collision in football, kick to head in soccer
• Take home: MRI in sport related concussion is an extremely low-yield study
Microhemorrhages
Postconcussion Syndrome

- Controversy over etiology (psychogenesis v.s. physiogenesis)
  - Premorbid differences
  - Coping and expectations
  - Secondary gain
  - Malingering
- DSM-IV v.s. ICD-10 definitions differed in symptom list
  - ICD-10 “hypocondriachal concern” and “adoption of sick role”
- Not mutually exclusive
  - Physiological dysfunction contributes to stress
  - Physiological process exacerbated by stress
Moderating Factors

• Multiple injuries
  • Studies that do not exclude patients with multiple injuries demonstrate greater cognitive impact (Belanger & Vanderploeg, 2005)

• Severity of injury
  • “complicated” mTBI
    • Poorer performance on neuropsych compared to other mTBI, despite equivalent LOC. (Levin et al., 2008)
    • Slower trajectory of sx recovery (Yeates et al., 2009)
Premorbid Factors

• Family history
  • Lagerreta, Brett, Solomon, & Zuckerman (2018)
    • Retrospective review of 154 high school athletes with concussion
    • PCS at 6 weeks post injury (defined as 3+ PCS sx)
      • Pts with personal psychiatric hx were 2.5 times more likely to demonstrate PCS
        • Especially those with anxiety and bipolar disorder
      • Pts with both a personal AND family history of psychiatric illness were 5 times more likely
    • Morgan et al., 2015 demonstrated similar findings

• Premorbid cognitive function (cognitive reserve)
  • Increased PCS in children with lower premorbid cognitive functioning (Fay et al., 2010)
Premorbid Factors

• Premorbid somatic symptoms
  • Nelson et al., 2016
    • Examined PCS symptom duration
    • Predictors included both preseason examinations and injury related factors (e.g. SCAT-3 sideline assessment)
  • Results
    • Preseason ratings of somatic symptoms (Brief Symptom Inventory-18) was the strongest predictor of symptom duration
    • SCAT-3 was the best injury-related tool

• Premorbid anxiety
  • Brooks et al., 2018
    • N=311 children with concussion
    • Around ¼ of children showed emotional concerns following injury (Parent rating forms: CBCL, SDQ)
    • Retrospective ratings of anxiety completed in ED predicted emotional concerns over injury characteristics
Figuring Out the Puzzle?
Roles of Neuropsychological Assessment

• Psychosocial history
• Assess postconcussive somatic symptoms
• Assess cognitive function
  • Comparison with estimates of premorbid or existing baseline data
• Assess emotional and behavioral functioning
  • Risk factors that might contribute to symptoms
• Interpretation
• Educate the child and family
  • Return to play
  • School services
  • Outpatient resources
• Monitoring
• Ideal model???
Baseline Model

• Assuring that cognitive symptoms have resolved before returning an athlete to play:
  • Lowers their risk of further injury
  • Mitigates the impact of second injury

• Measurement of cognition at baseline will allow for increased accuracy in detecting impairments and identification of concussed athletes
Psychometric Considerations

- Sensitive to the impact of concussion
- Specific to concussion
- Provide incremental validity
  - i.e. does baseline testing improve detection over symptom report alone?
- Reliability
- Practical considerations
  - Ease of administration, brief in nature, cost effective
Incremental Validity

- Good evidence for added value of Impact testing (with baseline assessment) over symptom report alone
  - Van Kampen et al., 2006
    - Repeated computerized assessment increases diagnostic accuracy over symptom report alone
  - Broglio et al., 2007
    - Neurocognitive impairment persists in some subjects despite subjective symptom resolution
What about reliability?

Definition of Statistics: The science of producing unreliable facts from reliable figures.
- Evan Esar
# Test-retest Reliability

<table>
<thead>
<tr>
<th>ImPact</th>
<th>Traditional Measures</th>
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<tbody>
<tr>
<td></td>
<td><strong>Reliability</strong></td>
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<tr>
<td></td>
<td><strong>CVLT-II</strong></td>
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<td><strong>NEPSY-II</strong> Memory for Designs</td>
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<td><strong>CPT-II</strong></td>
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<td></td>
<td><strong>WISC-IV Coding</strong></td>
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## ImPact Scores

<table>
<thead>
<tr>
<th>Measure</th>
<th>1-13 Days (M = 5.8)</th>
<th>45 Days</th>
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</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>.70</td>
<td>.23</td>
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<tr>
<td>Visual Memory</td>
<td>.67</td>
<td>.32</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>.79</td>
<td>.39</td>
</tr>
<tr>
<td>Processing Speed</td>
<td>.86</td>
<td>.61</td>
</tr>
</tbody>
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## Traditional Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Days</th>
<th>Reliability</th>
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</thead>
<tbody>
<tr>
<td>Learning (Trials 1-5)</td>
<td>M=21</td>
<td>.79</td>
</tr>
<tr>
<td>Immediate Recall</td>
<td>M=21</td>
<td>.73</td>
</tr>
<tr>
<td>Delayed Recall</td>
<td>M=21</td>
<td>.76</td>
</tr>
<tr>
<td>Immediate Recall</td>
<td>M=21</td>
<td>.72</td>
</tr>
<tr>
<td>Delayed Recall</td>
<td>M=21</td>
<td>.73</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>M=90</td>
<td>.55</td>
</tr>
<tr>
<td>Omissions (attention)</td>
<td>M=90</td>
<td>.84</td>
</tr>
<tr>
<td>Commissions (impulsivity)</td>
<td>M=90</td>
<td>.65</td>
</tr>
<tr>
<td>WISC-IV Coding</td>
<td>M=90</td>
<td>.84</td>
</tr>
</tbody>
</table>
Take Home Message w/ Automated Testing

• Advantages
  • Baseline comparison
  • Availability
  • Ease of use
  • Limited professional requirement

• Disadvantages
  • Utility in the absence of baseline testing
    • Weaker reliability relative to other neuropsychological measures
    • Weaker reliability after the post-acute phase of recovery

• Interpretation
Performance validity

• Performance validity concerns do occur in pediatric mTBI assessment, with varying rates:
  • 17% - Outpatient concussion/TBI clinic (Kirkwood & Kirk, 2010)
  • 28-37% - Compensation seeking clinic (Chafetz, Abrahams, & Kohlmaier, 2010).

• Poor effort has been noted in baseline testing of high school athletes
  • (Hunt, Ferrara, Miller, & Macciocchi, 2007) found 11% of their sample of 177 high school football players performed below cut off on a PVT.
Assessment of Performance Validity

• Observations from interview and testing
  • History of secondary gain
  • Child/parent appear to overstate symptoms or report a range of atypical symptoms
  • Patient appears reluctant or hesitant on testing tasks

• Embedded markers of performance validity
  • Performance on items within tests that are unexpected from a typical pattern of responding
    • Missing early, but not later items on a test with graded item difficulty
    • Recalling items on a memory test, but then failing to recognize them moments later
    • Below chance responding
    • Pattern responding (e.g. answering “C” on all items)
    • Validity markers in questionnaires (e.g. inconsistency, positive response bias, unusual items)

• Freestanding performance validity tests (PVTs)
  • Several well validated performance validity/symptom validity measures exist
Additional Factors in Performance Validity

• No one piece of evidence should be interpreted in isolation

• Not all patients with performance validity concerns are malingering
  • Potential alternative explanations:
    • Fatigue
    • Inattention
    • Seizure activity
    • Lack of comprehension

• Don’t be surprised if neuropsychologists are “cagey” in reporting evidence for performance validity in their reports
Treatment and Intervention
Interventions

• Cognitive rest
• Activity restrictions / return to play
• Parent/child education
• Collaboration with school
  • 504 plan
• Persistent symptoms
  • Behavioral health intervention
  • Cognitive rehabilitation (SLP/OT)
  • Physical therapy for balance
  • Medication treatment (headaches, etc.)
"The cornerstone of concussion management is physical and cognitive rest until the acute symptoms resolve and then a graded program of exertion before medical clearance and RTP."

• Initial period of rest (24-48 hours)
  • Reduced cognitive, physical, and social activities by restricting:
    • School attendance
    • Academic work
    • Electronic usage

• Prolonged cognitive/physical rest???
Rest

- Silverberg & Iverson 2013
  - Complete physical rest exceeding 3-7 days has no added benefit
  - Gradual resumption of physical activity should begin as soon as tolerated (with the exception of activities that have a TBI exposure risk)
  - Supervised exercise may benefit patients with persistent symptoms
Limited evidence for efficacy of cognitive rest
  • Particularly prolonged rest
• Williamson’s activity model of depression
Proposed Model
Neuropsychological Management of Concussion

Acute (<1 week)

- Achieve accurate diagnosis
  - Sideline assessment
    - Symptoms reported by athlete
    - Neurologic function
    - Balance, postural stability
    - Cognition, orientation
  - Primary care
- R/O medical emergencies
  - e.g. subdural hematoma
- Removal from play (until full sx resolution)
- Utilize automated testing where baseline is available
- Monitoring
- Cognitive and physical rest
- Education for child and parents
- Preparing school for immediate absences

Pocket SCAT2

Concussion should be suspected in the presence of any one or more of the following: symptoms (such as headache), or physical signs (such as unsteadiness), or impaired brain function (e.g. confusion) or abnormal behavior.

1. Symptoms
   Presence of any of the following signs & symptoms may suggest a concussion.
   - Loss of consciousness
   - Seizure or convulsion
   - Amnesia
   - Headache
   - "Pressure in head"
   - Neck Pain
   - Nausea or vomiting
   - Dizziness
   - Blurred vision
   - Balance problems
   - Sensitivity to light
   - Sensitivity to noise
   - Feeling slowed down
   - Feeling like "in a fog"
   - "Don't feel right"
   - Difficulty concentrating
   - Difficulty remembering
   - Fatigue or low energy
   - Confusion
   - Drowsiness
   - More emotional
   - Irritability
   - Sadness
   - Nervous or anxious

2. Memory function
   Failure to answer all questions correctly may suggest a concussion.
   - "At 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?"

3. Balance testing
   Instructions for tandem stance
   "Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. You should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."
   Observe the athlete for 20 seconds. If they make more than 5 errors (such as lift their hands off their hips; open their eyes; lift their foot off or heel; step, stumble, or fall; or remain out of the start position for more than 5 seconds) then this may suggest a concussion.

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, urgently assessed medically, should not be left alone and should not drive a motor vehicle.
Post Acute (1 week-3 months)

- Multidisciplinary concussion evaluation
  - Concussion medical specialist
  - Evaluation by additional specialties
    - Rehabilitation therapists (SLP, OT, PT)
    - Consideration of cognitive rehabilitation therapy
  - Continue automated testing until return to baseline
- Neuropsychological consultation
  - Brief assessment of PCS and cognitive function most sensitive to concussion
  - Consider psychotherapy in cases with significant premorbid psychiatric indications
- Discontinue cognitive rest
- Begin monitored/graded return to activity
- Continued precaution for repeat injury
  - Activity restriction from contact and velocity sports
- Education for family/child regarding expected recovery
- Academic adjustment
  - Reduced academic load, where possible
  - Consider 504 plan
Long term (>3 months)

- Multidisciplinary concussion evaluation
  - Concussion medical specialist
  - Rehabilitation therapists (SLP, OT, PT)
    - Cognitive rehabilitation therapy encouraged
  - Neuropsychological consultation
    - Comprehensive assessment of PCS, neurocognitive function, and emotional functioning
    - Recommend psychotherapy

- Continue monitored/graded return to activity
- Continued precaution for repeat injury
  - Activity restriction from contact and velocity sports
- Education for family/child regarding expected recovery
- Academic adjustment
  - Graded return to full school
  - 504 plan or IEP
Thank You!