Definition

• A traumatic brain injury is “an insult to the brain, not of a degenerative or congenital nature, caused by an external force, that may produce a diminished or altered state of consciousness” (National Head Injury Foundation, 1985).
  – Key: an acquired injury that is caused by an external mechanical force such as blow to head, concussive forces, acceleration-deceleration forces, or projectile missile

Classification of Initial Severity

• Severity of traumatic brain injury most often assessed with a Glasgow Coma Scale score (GCS; Teasdale & Jennett, 1974)
  – measures level of consciousness based on three observable variables: Eye Opening (4) + Best Motor Response (6) + Verbal Response (5)
  – Coma Score (E + M + V) = range 3-15
  – used to grade initial severity into categories of mild, moderate, and severe

Spectrum of Injury

• Acute Injury Characteristics
  – Mild: GCS 13-15 LOC < 20-30 minutes
• Typically fully alert to mildly confused; no deterioration of GCS or focal neurological deficit
  – Moderate: GCS 9-12 or >12 with complication or focal brain lesion on neuroimaging
    • Typically clearly impaired consciousness
  – Severe: GCS 3-8  Coma duration >/= 6 hrs
    • Initially comatose or deteriorate into coma (no eye opening, no motor response to command, no comprehensible words spoken)

Concussion
• Concussion is essentially a mild traumatic brain injury
  – Latin concussus meaning “a shaking”
  – “…a trauma-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion” (Practice Parameter, Quality Standards Subcommittee, American Academy of Neurology, 1997)

Concussion
– Brief/transient disorientation or loss of consciousness
– Anterograde amnesia: 5-10 minutes
– Retrograde amnesia in more severe cases
– Normal acute head CT

Summary of Outcomes

• Severe
  • Almost always causes substantial, persisting impairments across a range of functions and significant disability
• Moderate
  • More like severe TBI than mild TBI
• Mild
  • vast majority of older children and adults recover well within weeks to 3 months
  • pain problems add considerable complications
  • persistent post-concussive syndrome (15% of cases)

Historical Perspectives
• Differential outcomes for different grades of traumatic brain injury
  – Barth et al. (1989) “College football study”
• Increased awareness of the incidence of traumatic brain injury in sports
  – 1980s medical/public health concerns
  – High profile cases/elite athletes (1990s)
    • Forced retirements of high-profile athletes
• Growing research literature documenting that children and adolescents are more vulnerable to the effects of neurological trauma, including TBI
Historical Perspectives

• 1904: 19 student athletes were killed or paralyzed playing football
  – Concerns about growing brutality
    • Leaders from Harvard, Yale & Princeton decide to change rules to ban mass formations and gang tackling
• 1906: President Teddy Roosevelt established the Intercollegiate Athletic Association of the US (becomes NCAA in 1910)
• 1980s: Pro Football bans “spearing”
  – Greater attention paid to protective gear

Historical Perspective

• Prior to 1980s, mTBI received limited attention
• Disagreement: definition, expected course of recovery, role of psychological factors, and pathophysiological mechanisms of mTBI
• Research problem: use of controls & accounting for effects of premorbid functioning
  – Sports as a natural clinical laboratory

University of Virginia Study of Mild Head Injury in Football

• Sample
  – 10 site study of 2350 college football players
  – Prospective longitudinal data collection: pre-season baseline, 24h, 5 days, & 10 days post-injury
  – 195 athletes sustained concussion in 1987 season compared to orthopedic & non-concussed subjects
• Findings
  – A single mTBI causes cognitive-information processing deficits at 24h and 5 days later compared to baseline (including self-report of headaches, dizziness, memory problems)
  – NP measures are sensitive to concussion effects
  – Recovery occurs in 5 to 10 days
  – SLAM: Sports as a Laboratory Assessment Model
    • Set a methodological standard

Epidemiology

• A major public health concern: the “silent” epidemic
• Incidence
  – 2 million per year; 75,000 die annually from TBI
  – Peak age of incidence: 15-24 years and increase again > 60-65
  – Males:Females::2-3:1 after age 5
  – Adults: 85% mild; 8% moderate; 5-6% severe
  – Children: 76% mild; 10% moderate; 13-24% severe
    • 30% of all deaths related to childhood injury result from TBI (case-fatality ratio greatest in kids < 5)
    • 25% of hospital admissions for TBI in kids < 2 years are due to abuse
Epidemiology: Causes

- Most common (Kraus, 1995)
  - Transportation-related (motor vehicles & bicycles)
  - Falls
  - Sports/recreation accidents
  - Interpersonal violence (assault/abuse)
  - ETOH in 56% of cases
- Distribution of causes varies based on age
  - Infants & young children: falls, violence
  - Older children: sports & recreational accidents; pedestrian or bike collisions with motor vehicles
  - Adolescents & young adults: MVAs
  - Elderly: falls

Athletes: An At-Risk Group

- Conservative Estimates:
  - 300,000 sports-related concussions per year (CDC, 1997)
    - 10% of all athletes involved in contact sports suffer a concussion each season
    - Increased risk during games v. practice
  - At least 1.25 million HS athletes in contact sports
  - High School contact sports produce 62,816 concussions/year (Powell & Barber-Foss, 1999)
    - Football players account for 63% of cases
    - Tackling or being tackled seem to cause the most injuries (about 60%)
  - College football players most at-risk
    - 34% with one concussion
    - 20% with multiple concussions

Athletes: An At-Risk Group

- 30-55% college athletes reported at least one mTBI prior to college (Echemendia, 1997)
- Guskiewicz et al. (2000)
  - Surveyed ATCs who worked in high school and collegiate football
    - Of the 17,459 players:
      - 5.1% sustained at least one concussion
      - 14.7% of those sustained a second concussion in the same season
      - greatest incidence was found in high school and Division III collegiate levels

High School Athletes

- Based on participation levels, HS athletes represent the largest majority of at-risk athletes
- Fewest resources to identify and manage risk
  - Less medical supervision/control
- Difficult to estimate true incidence
- Heterogeneity of symptom presentation
  - Varying definitions of concussion/dx criteria
  - Symptoms go unrecognized
- Athletes reluctant to report symptoms
– Jeopardize status on team
– “Play through” concussion
– “If you’re in the tub, you’re not on the club.”

Some High Profile Cases
• M. Ali (1988 Olympics Torch Bearer)
• Al Toon, NY Jets Wide Receiver
• Merril Hoge, Steelers Running Back
• Steve Young, SF 49ers QB
• Troy Aikman, Cowboys QB
• Eric Lindros, the Next One

The Challenge

“I don’t want guesswork for my players. Give me objective data for return to play.”
Chuck Noll, Head Coach
Pittsburgh Steelers, 1990

“It hurts not being able to play. But it hurts more not being able to think.”
Merril Hoge, Former NFL Running Back

Merril Hoge
• 7 year NFL veteran as a Running Back
• Injured on running play
• History of 4-5 concussions during one season
• Initial symptoms included LOC (seconds), retrograde amnesia for game, confusion on sideline, irritability, feeling “drunk”
• Lengthy recovery and eventual retirement in 1994

Merril Hoge
• “I thought a concussion meant a player was knocked out…I thought of times on the team bus when we would talk about the guy who got knocked out and then tried to go to the other team’s huddle. Incidents like that weren’t anything of great concern to me as a player. They were something funny, not worrisome.”

Pediatric Outcomes of mTBI
• Recent meta-analytic review of pediatric literature suggested that permanent adverse effects (> 1-3 months) of a single mTBI in any outcome domain are uncommon (Satz & Zaucha, 1998)
• Unresolved issues
  – Spectrum of severity within the category of mild
  – What is needed is an operational definition of injury severity along multiple dimensions
  – More variable outcome in context of learning problems, hyperactivity, abuse
  – Cumulative effects of multiple injuries
  – Age at time of injury

Maturational Change

• Adult
  – presumed full maturity of brain systems: deficit is commonly expressed as loss of function

• Child (Taylor & Alden, 1997)
  – brain development proceeds at different rates in different regions of the brain
  – child TBI may have at least 3 general effects:
    • injury to a mature brain system: loss of function
    • injury to a developing system: alteration or delay of function
    • injury to a brain system(s) not yet “on-line”: failure to mature or highly abnormal trajectory

Primary Clinical Concerns

• Rule out more serious intracranial pathology
• When to resume play after a concussion
  – No evidence-based guidelines for return to play decisions
  – Risk/prevention of second impact syndrome (SIS)
• Effect of multiple concussions
  – Possibility of cumulative effects of repeated trauma
• Effect of age, gender, and interval between concussions
• Goal: safe return of concussed athlete to play

Neuropathological Mechanisms

• Two basic mechanical forces produce TBIs
  – Contact/Collision
    • causes distortions or fractures of the skull with contusion or laceration at point of contact
    • coup/countrecoup contusions
  – Inertial loading (acceleration/deceleration)
    • common in contact/collision sports
    • strains the brain tissue leading to damage
    • damage based on direction and degree of rotational force
    • tension, compression, shearing

Biomechanical Forces

• Rapid deceleration due to impact with stationary or opposing forces
  – Newtonian physics: a football player running at 10 ft/sec will decelerate at a rate of 9.3g after making contact with another player and stopping within two inches
– Forces acting on brain are 9.3x that of its resting weight
– Neuronal damage is a function of mass, weight, velocity, hardness and surface area of the impacting objects

**Acute Mechanisms of Injury**

- 1. Direct contusion
- 2. Direct/gliding contusion on bony protrusions at base of skull (anterior fossa)
- 3. Contrecoup contusion
- 4. Shearing forces (DAI)
- 5. Stretching & tearing of bridging veins along convexity (SDH)
- *Most TBI involves shaking and impact*

**Metabolic Effects of Concussion**

- Hovda et al. (1999) animal-rodent models document metabolic dysfunction
- Glucose metabolism *increases* early after TBI (*hyperglycolysis*) in an attempt to maintain energy
- Blood flow or CBF (and glucose delivery) decreases after trauma.
  - Duration of decreased CBF seems to be critical in determining neurological outcome
- Results in a period of energy crisis that can last *up to* 10-14 days
  - Most experts believe that neurocognitive manifestations are related to acute metabolic dysfunction
- Period of vulnerability during which secondary insults should be avoided.

**Energy Crisis**

- Biomechanics result in tissue movement
- Tissue movement results in physiological changes
- Levels of ATP are critically low post TBI
- Energy demand could overwhelm energy production
- Fuel for metabolism could be insufficient
- Mitochondria could be dysfunctional (due to increased intracellular calcium)
- These metabolic changes after TBI in humans occur at all levels of injury severity
- Energy demands and metabolic dysfunction combine to produce an energy crisis—injury induced state of vulnerability

**Neurophysiology**

- Time periods for post-traumatic physiological brain abnormalities (dysautoregulation) in humans can last days to weeks or months.
- Implication: overly simplified clinical assessment may not detect phases of altered brain physiology and, hence, vulnerability.
  - Careful clinical examination of the recently head-injured athlete is crucial.

**Developmental Aspects**

- Initial data suggests HS athletes may recover more slowly than collegiate counterparts (Collins et al., 1999)—symptoms appear to last longer
– Biomechanics
  • Thinner skull
  • Greater proportional cranial mass
– Energy Metabolism
  • Increased basal cerebral glucose metabolism
– Vascular Reactivity and Autoregulation
  • Greater brain water content
  • Increased susceptibility to cerebral edema
– Neurotransmission
  • Increased excitatory amino acid receptors

Neurophysiology
• Excessive activation of the recently injured brain can lead to increased damage and worsen recovery.
• The developing brain may be uniquely vulnerable to diffuse brain injury.
  • Deford, Wilson, et al., J Neurotrauma, 2002
    – In animal studies, a single mild TBI did not cause cognitive problems
    – But multiple mild TBI did result in learning deficits

Second Impact Syndrome (SIS)
• First described in 1973 (Schneider)
• Term SIS in 1984 (Saunders & Harbaugh)
• When an athlete who has sustained an initial head injury, most often a concussion, sustains a second head injury before symptoms associated with the first have fully cleared (Cantu, 1995)
  – Mortality rate of 50%, morbidity rate of 100%
• Since 1984:
  – 26 SIS-related deaths (Maroon et al., 2000)
  – Most in High School athletes

Second Impact Syndrome
• The second impact sets in motion the rapid development of cerebral vascular congestion
  – Malignant cerebral edema
• Causes increased intracranial pressure
• Often results in brainstem herniation and death
• Estimated that the immature/less mature brain is 60 times more sensitive to glutamate-mediated NMDA excitotoxic brain injury (Field, 2002)
• Possibility of SIS underscores the importance of reliable assessment and return to play criteria

Second Impact Syndrome
• Onset within 15 seconds to several minutes
• Symptoms include collapse, rapid decline in mental status, loss of eye movement, respiratory failure
• Thought to involve a loss of autoregulation of the brain’s blood supply
• Cerebrovascular engorgement-->increased ICP-->herniation of medial surface of TL (uncus) or lobes below tentorium
  – Brainstem failure can be as quick as 2-5 min
• Animal models suggest the process is nearly impossible to control (Cantu, 1996)

Second Impact Syndrome
• SIS remains a controversial issue
  – An indistinct and poorly understood diagnostic entity
  – One attempt to provide diagnostic criteria failed to identify any of 17 cases as definite SIS (McCrory & Berkovic, 1998)
  – In 12 cases, the possibility of SIS was ruled out

Baseline NP Testing
• Revisiting Barth et al. (1989) paradigm
• Mark Lovell (U Pittsburgh Medical Center) establishes first clinically oriented program to inform post-concussion RTP decision-making with the Pittsburgh Steelers
• Why use a baseline?
  – Uncertainty about when brain normalizes
  • Prior studies documented sensitivity of NP
  – Allows assessment of pre-existing factors that might influence testing
  – High variability among athletes

NFL Concussion Program
• 1995: NFL establishes MTBI Committee
• League-wide network established
• 29 teams now participating (2002)
• Test results used as tool in evaluating recovery and informing RTP decisions

NFL Concussion Project
Testing Protocol
• Pre-Season Baseline (prior to contact drills)
  – Concussion History
  – Neuropsychological Evaluation
• 24-48 Hours Post-Injury
  – Repeat Neuropsychological Evaluation
• 5-7 days Follow-up
– Repeat Neuropsychological Evaluation

**Postconcussion Symptoms Scale**

(Adapted from Lovell and Collins, *Journal of Head Trauma and Rehabilitation* 1998; 13:9-26)

**Postconcussion Scale**

• Essentially a “state” measure of perceived symptoms associated with concussion.
  
• Athlete is asked to report his/her “current” experience of the symptoms.
  – Allows for tracking of symptom levels over very short intervals, such as consecutive days or every few days.

**Postconcussion Scale**

Iverson, Lovell, Podell, & Collins (2003)

• HS-Regular Education
  – Boys (n = 588)  M = 4.8 (sd = 7.9, 0-54)
  – Girls (n = 199)  M = 7.7 (sd = 13.7, 0-78)

• HS-Special Education
  – Boys (n = 156)  M = 8.8 (sd = 13.0, 0-64)
  – Girls (n = 31)  M = 5.3 (sd = 6.3, 0-26)

• Note: women report more sxs than men, and those with a SE/learning problem history report more symptoms than those without.

**Postconcussion Scale**

• Athletes with concussions
  – Males (n = 83)  M = 26.8 (sd = 20.2)
  – Females (n = 32)  M = 35.8 (sd = 25.2)

**How Long Does It Take The Athlete to Recover?**

• Lovell, Collins, Maroon, Cantu & Powell (2002)
  – N = 210 athletes suffered concussion in 01-02 season
    • Males = 172, Females = 38
    • 143 high school, 41 college, 26 others
    • Evaluated at 2, 5, & 8 days post-injury
    • Compared with 50 HS & college controls

**How Long Does It Take?**

• Lovell et al. (2002) findings:
  – ImPACT Memory Composite
    • Significant difference between groups out to 8 days post-injury
  – ImPACT Reaction Time Composite
• Significant difference between groups out to 5 days post-injury
• Importantly, self-report of symptoms resolved by day 4 post-trauma in all Ss
• By days 5 and 8: better than baseline

How Long Does It Take?

• Implications:
  – Corresponds with animal models of concussion and its resolution
  – Such findings bring into question the common practice of returning mildly concussed athletes to the context in which they are injured.
    • Especially when relying on athlete report
  – Data also contradict widely used grading systems (such as AAN)

Significance of On-Field Markers of Concussion

• Examined the significance of LOC, amnesia, and disorientation
• 78 HS/college athletes with concussion
• All athletes received baseline ImPACT
• Athletes re-evaluated within 72h post-concussion
  – “Good” outcome in 44 athletes
  – “Poor” outcome in 34 athletes
• Groups compared on presence of on-field markers of concussion following in-study injury (determined by ATCs)

On-Field Markers Summary

• Athletes with on-field retrograde amnesia are 10x more likely to have “poor” early outcome
• Athletes with on-field anterograde amnesia are 4.2x more likely to have “poor” acute outcome.
• LOC not predictive of outcome.
• Disorientation not predictive of outcome.
• Athletes with 3-4 on-field markers are 15.3x more likely to have poor outcome.

Useful On-Field Markers of Severity

• 125 concussed HS & college athletes
  – Preseason and 24-48h post-injury ImPACT
• On-field retrograde and anterograde amnesia predicts measurable neuropsychological performance decrements 24-48h post-injury.
• LOC did not predict early neuropsychological performance.

Implications

• Need for careful post-injury follow-up
• May be prudent to remove HS athlete from contest (do not return to play same day)
• Recovery from concussion may not be linear process
• Need for further research with “mild” concussion
• Replication needed with college/professional athletes

Do Current Grading Systems Detect Mild Concussion?

• Lovell, Collins, Iverson, Johnston, Maroon, & Fu (2003)
  – N = 43 high school athletes with Grade 1 concussion (AAN, 1997)
  – 81% male; 56% football players
  – All athletes diagnosed with “bell ringer” or “ding”
    • Confusion, amnesia, signs/symptoms cleared within 15 minutes
    • No athlete sustained loss of consciousness
    • No athlete returned to play in contest
  – ImPACT evaluation obtained at baseline, 2 & 6 days post-concussion

Concussion Grading Systems

• Cantu (2001)
  – Emphasizes post-traumatic amnesia
    • Mild: PTA < 30’
    • Moderate: PTA > 30’ or LOC < 5’
    • Severe: PTA > 24h or LOC > 5’

• American Academy of Neurology (1997)
  – Emphasizes LOC
    • Mild: sx < 15’
    • Moderate: sx > 15’
    • Severe: any LOC

Do Current Grading Systems Detect Mild Concussion?

• ImPACT Memory Composite and Symptom Total Scores were significantly different at day 2 post-injury (but not day 6)

“Bell-Ringer” Summary
  – Findings challenge assumption that Grade 1 concussion is associated with rapid and complete recovery

Implications
• Findings challenge assumption that Grade 1 concussion is associated with rapid and complete recovery
  – Need for careful post-injury monitoring
  – Prudent to remove HS athlete from play that day
  – Recovery from concussion may not be a linear process (perceived symptoms resolve before performance on ImPACT)

**Multiple Prior Concussions**

• Do multiple prior concussions lead to a lowered threshold for concussive injury? (Collins, Lovell, Iverson, Cantu, Maroon & Field, 2003)
  – N = 173 HS/college concussed athletes
  – Design: Groups determined by concussion history
    • N = 45: no concussion history
    • N = 27: 3+ concussions
  – Groups compared re: presence of on-field LOC, retrograde amnesia, anterograde amnesia following in-season concussion

**On-field concussion severity markers by concussion history group**

**Multiple Prior Concussions**

• On-field severity markers of concussion were significantly more frequent for those athletes with a concussion history
  – LOC odds ratio = 6.7 (p < .005)
  – RA odds ratio = 2.7 (p < .05)
  – AA odds ratio = 3.8 (p < .019)
  – At least two hypotheses:
    • Increased sx vulnerability
    • Lower threshold for concussion

**To Play or Not to Play: Significance of Post-Concussion Headache**

• 109 High School athletes with concussion
  – 84% male; 64% football players
• Prospective cohort study: athletes evaluated via ImPACT on post-injury day 7
  – 73 (66%) reported no HA at follow-up
  – 36 (34%) reported some degree of HA
• Groups compared on ImPACT composite and symptom scales at day 7
  – No baseline differences between groups
    » (Collins et al., 2003)

Relevance of Headache Symptoms
• Athletes reporting post-traumatic headache showed worse performance on ImPACT reaction time and memory composite scores.
  – Also: more post-concussion symptoms & more likely to have demonstrated on-field anterograde amnesia (ES = .80)
• Any degree of lingering headache in HS athletes is likely associated with incomplete recovery.
• Conservative management indicatedz’ never return to play with HA
  – (Collins et al., 2003)

Recovery from Mild Concussion in HS Athlete
• Sample (Lovell, Collins, Iverson et al., 2003)
  64 concussed (no LOC) HS athletes (60 males)
  24 non-concussed HS athletes (16 males)
• Protocol
  • Preseason baseline testing & history
    – Non group x group baseline differences
  • Tested post-injury: 36h, 4 days, 7 days
• Key Findings (similar to prior college athlete study)
  – Even in mildly injured group, there was pronounced memory decline in some HS athletes that remained at least 7 days
  – In contrast, self-report symptoms showed resolution within 4 days

Age and Recovery
  – Compared recovery rates from concussion in 92 HS v. college athletes
    • HS athletes showed prolonged memory dysfunction
    • HS athletes performed significantly worse than age-matched controls at 7 days post-injury
    • College athletes (despite more severe in-season concussions) displayed commensurate performance with matched controls by day 3
    • Perhaps require age-based RTP guidelines v. assuming standards apply for all age groups and playing levels

Summary
• Accurate on-field diagnosis of concussion is critical.
• Need for careful post-injury assessment of symptoms and cognitive status.
  – PCS is a useful tool, especially acutely
  – NP testing has demonstrated good sensitivity to effects
• Athletes may not return to play until symptom free at rest and exertion.
– Mean window of vulnerability 5-10 days
– Majority of athletes with one concussion likely to have good recovery, but...
• Specific assessment tools are available for the sports-medicine clinician.
• Evidence-based RTP guidelines are forthcoming.

Sports-Related Concussion in High School Athletes:
Assessment and Management
Part II
Anthony J. Giuliano, Ph.D.
MA Statewide Head Injury Program
Art Maerlender, Ph.D.
Dartmouth Medical School

Clinical Management: RTP
• Clinical Management Guidelines
• On-field assessment
• Concussion assessment programs
• Establishing a concussion program

Clinical Management
• Individual decision-making that depends upon:
  – Athlete’s concussion history
  – Severity of the injury
  – Duration of symptoms
  – Time between injuries
  – Availability of experienced/trained personnel to conduct repeated assessments and monitor recovery

Clinical Management
• Postconcussion Checklist
• Neurological/neuropsych evaluation
• Athlete with any postconcussion symptoms
  – prohibit RTP in game or practice
  – do not leave athlete alone
  – insure regular monitoring until symptoms resolve
  – if symptoms not cleared by end of game or in 15 minutes, refer for medical evaluation
When in doubt, sit them out.

Clinical Management

• Do not return an athlete to competition until:
  • Normal neurological assessment
  • Asymptomatic at rest and exertion
    – No athlete should be returned to play while still symptomatic first at rest and then exertion
    – Includes presence of post-traumatic headache
  • If available, performance on neuropsychological battery is at baseline or above
  • If athlete experienced LOC or amnesia, should not RTP that day.

Gradual Return to Play

• RTP follows a graduated step-wise process
  – While symptomatic, rest/activity restriction.
    • No substance use
  – Once asymptomatic, engage in light aerobic activity (e.g., walking, stationary cycling)
  – Sport-specific activity (e.g., skating in hockey, running in soccer)
  – Non-contact training drills
  – Full contact training after medical clearance
  – Return to regular game play

Conclusions

• Finding a balance between what is safe and what is “fair” and practical.
• Use a conservative criterion
  – “When in doubt, sit them out.”
• Concussions as “career killers”
  – Better understanding of reasons athletes continue to play after sustaining a medically significant concussion(s)

AAN Guidelines for Return to Play After a First Concussion

AAN for Return to Play After a Second or Third Concussion
On-Field Identification

• The challenge
  – signs and symptoms may be subtle
  – no loss of consciousness or incoordination
  – athlete reluctance to report initial symptoms

• Use of standard sideline evaluation
  – Sideline Concussion Checklist
  – Other evaluations

On-Field Identification

• Sideline Concussion Checklist (Kutner & Barth, 2001)
  – Provides a format for evaluating athletes who have sustained a sports-related MHI or concussion
  – It functions as a checklist and is not a scale
    • Time of injury, LOC, pupillary response, orientation, thumb-to-fingertip sequencing, vomiting, headache, dizziness, nausea, dysmetria, diplopia, tandem gait, cognitive status, exertion stress test.

On-Field Identification

• Signs Observed by Staff
  – Appears to be dazed or stunned
  – Is confused about assignment (play, position)
  – Is unsure of game, score, or opponent
  – Moves clumsily
  – Answers questions slowly or forgets plays
  – Loses consciousness
  – Shows behavior or personality change
  – Forgets events prior to play (retrograde)
  – Forgets events after hit (anterograde)

On-Field Identification

• Symptoms Reported by Athlete
  – Headache
  – Nausea
  – Balance problems or confusion
  – Double or fuzzy vision
  – Sensitivity to light or noise
  – Feeling sluggish
  – Feeling foggy
  – Change in sleep pattern
  – Concentration or memory problems
Standardized Assessment of Concussion

Orientation

• Ask the athlete the following questions.
  – What stadium is this? What month is it?
  – What city is this? What day is it?
  – Who is the opposing team?

Amnesia

  Anterograde amnesia (new learning)

• Ask the athlete to repeat the following words.
  • Girl, dog, green

  Retrograde amnesia

• Ask the athlete the following questions.
  • What happened in the prior quarter/period?
  • What do you remember just prior to the hit?
  • What was the score of the game prior to the hit?
  • Do you remember the hit?

Concentration

• Ask the athlete to do the following.
  • Repeat the days of the week backward (starting with today).
  • Repeat these numbers backward:
    • 63 (36 is correct) 419 (914 is correct)

  Word list memory

• Ask the athlete to repeat the three words from earlier.
  (Girl, dog, green)

• Any failure should be considered abnormal.
• Consult a physician following a suspected concussion.

Sports-Concussion Testing Software

• ANAM
  – Automated Neuropsychological Assessment Metrics (Reeves, Throne, Winter, & Hegge, 1989)

• CRI
– Concussion Resolution Index (Erlanger et al., 2001)
  • Web-based program (Headminder)
• CogSport
  • Web-based program
• ImPACT
  • Freestanding Windows-based application run on PCs or networks (has Spanish version)

The Unconscious Athlete
• Do not move the athlete.
• Do not remove the helmet.
• Do not use ammonia inhalants, which may cause the head to jerk from the noxious stimulus.
• Do not give liquids or food.
• Do not rush the evaluation.
• Do not worry about delaying the game.

RTP: Computer-Based Testing
• Advantages Over Traditional Testing
  – Minimizes practice effects
    • improved reliability
  – Measures reaction time to 1/100th sec
    • improved sensitivity
  – Can be administered in a group setting
    • more efficient
  – Can be administered by athletic trainer
    • more practical

Negative Aspects
• Cost can be high for limited school budgets
• Faking bad at baseline
• Availability of professional support
• Sensitive but not specific
• Must be supported by coaches

ImPACT
• *Immediate* Post-concussion Assessment and *Cognitive Testing*
  – Promote safe return to play through timely evaluation
  – Develop a better understanding of recovery
– Investigate the relationship of test performance to functional/anatomical brain imaging
– Evaluate the role of protective equipment

**ImPACT**

- Symptom Inventory
- Word Memory
- Design Memory
- Xs and Os
- Symbol Matching
- Color Match
- 3 Letters (trigrams)
- Self-report of symptoms
- Verbal memory
- Visual memory
- Visual working memory
- Processing speed/memory
- Reaction time
- Working memory/processing speed

**Symptom Inventory**

Word Discrimination
Design Memory
X-O's
Symbol Matching
Color Match
3 Letters

**Verbal Memory Composite**
**Visual Memory Composite**

**RT Composite**
**Proc. Speed Composite**

**Further Information**

- [www.impacttest.com](http://www.impacttest.com)
- [www.concussionsafety.com](http://www.concussionsafety.com)

**Making the call:**

Case studies
How can you know when they have fully recovered and are ready for safe RTP?

• Case example
  – 19 y.o. RB makes helmet-to-helmet contact with LB
  • 5" LOC, no self-report of sx, passes SAC at 5, 10, and 15 minutes
  – Colorado Guideline
    • Grade 3, hospital evaluation, no practice/play for month and asymptomatic 2 weeks (rest & exertion)
  – AAN Guidelines
    • Grade 3: Disallow RTP for 1 week if sx free
  – Cantu Guidelines
    • Grade 2, RTP in 1 week if no sx rest/exertion

H.S. Lax player
15-yr. old. Male. Unknown mechanism of injury...struck in the chest initially and in the lower back. Whiplash potential, unsure of other mechanisms. No pretest

Concussion Details
• Loss of consciousness 1-20 seconds
• Retrograde amnesia > 15 minutes
• Anterograde amnesia 31-180 minutes
• Confusion / disorientation > 30 minutes
• Taken to hospital Yes
• CT/MRI scan of head Negative
• Symptoms headache, nausea, personality change, numbness or tingling, fatigue

Memory composites
HS Lax Composites
HS Lax
Symptoms
Symptom Totals
Sx. Graph
JM: Female rugby player
JM Symptoms
JM score profile
JM Disposition

• Did not return to play
• Scheduled for full NP eval.

Concussion Management Program at the High School Level

• What’s needed?
  – Commitment from team physician and AT-C and/or school nurse
  – AD and coaches approval
  – For computer-based assessment program: Computer lab at school with tech support
  – Policies and procedures for testing and handling mTBI events in student athletes
  – Support personnel for student athletes: consulting neuropsychologist, school counselor or school psychologist, tutors/liaison

Concussion Management Programs at the High School Level

• Prevention through education
• Education/Awareness: AD, ATC, coach, players, parents, teachers, school personnel
• Skills development as a protective factor
  • Teaching proper technique
  • Time, skill, persistence
  • Train in protective behavior

Fitness as protection
  – Being in shape allows skilled performance
  – Developmental aspects of conditioning
    • More is not necessarily better
  – Monitor fatigue during practices and games
  – Neck muscle conditioning
    • Possibility of reducing impact forces, but no evidence

Equipment and rules
  • Proper fit and maintenance of equipment is important
  • Use of equipment needs teaching and monitoring
  • Unintended consequence of “invulnerability”
  • KEY: Rules modifications and enforcement
    – No spearing in football, no head checking in hockey
  • Enforcement of rules
    – game rules, coach’s rules, School rules, MD’s rules
    – Modify rules of games as needed

Sports Medicine

• Get organized (A.D.)
• Use of EMT’s, school nurses, MD’s, trainers
  – Make sure to have established a connection for follow-up prior to the start of the season
  – Verify concussion protocol
  – Coaches should not do on-field assessments during competitions
• Use of testing protocols
  – Availability, costs, reliability

**H.S. Concussion Program**

• Collaborate
  – With schools in your conference, division
• Advocate
  – E.g., for state level action (e.g., NH Interscholastic Athletic Association (NHIAA))
• Initiate
  – A process for assessing needs, resources and responsibilities

**Educational outcomes**

• Educating the educators
  – Recovering student athletes may require short-term modification of their educational program
  – Administrators, school psychologists

**Summary**

• Accurate on-field diagnosis of concussion is critical.
• Need for careful post-injury assessment of symptoms and cognitive status.
  – PCS is a useful tool, especially acutely
  – NP testing has demonstrated good sensitivity to effects
• Athletes may not return to play until symptom free at rest and exertion.
  – Mean window of vulnerability 5-10 days
  – Majority of athletes with one concussion likely to have good recovery, but...
• Specific assessment tools are available for the sports-medicine clinician.
• Evidence-based RTP guidelines are forthcoming.

**What we think we know**

• Prevention is the best intervention
• Concussions (mTBI) can produce lasting negative effects
• Multiple concussions makes the chances of more/severe concussions greater
• Amnesia is the best indicator of severity
  – Orientation and LOC are not good markers for severity
• Err on the side of caution

Future Matters

• Role of exertion on recovery from concussion and utility of stress test in RTP?
• Longitudinal studies of outcome
  – Long term effects for whom, when, and in what context?
  – Role of prior events/history & genotype (ApoE-4)?
• Value of research examining component symptoms of concussion to inform evidence-based clinical management.

What we need to know

• Are some athletes more susceptible to
  – initial concussion?
  – multiple concussions?
• Do subsequent concussions occur with less trauma?
• What leads to post-concussive syndrome?
• What leads to second impact syndrome?
• What impact might steroids or other drug use/abuse have on metabolic dysregulation and vulnerability

What we need to know

• What function(s) is most vulnerable to disruption?
• Are grading systems accurate/useful?
• What should the RTP guidelines be?
• Does concussion “grade” matter?
• How close together can multiple concussions be?

Thank you