Neurosurgical Aspects of Diagnosis and Management of Sports Injuries

Petra M Klinge
Department of Neurosurgery
Rhode Island Hospital
Disclosures

✓ No financial conflict of interest
Introduction

Significant impact of TBI:

- Head injury most frequent cause of acquired brain insults in children: ~100 hospitalizations per 100 000
- Head injury accounts for ~ 40 to 50% of injury deaths in children
- US in children <15 yrs: 3000 deaths, 30 000 hospitalizations, 300 000 emergency department visits per year
- $ 12 billion year Health costs !
- Most frequent are transportation accidents (i.e. motor vehicles and bicycles) and falls _75-80%

- However, sports related injuries are increasing
  - Sports in the modern society has little boundaries
  - Instead, is socially important and provides high esteem, offers career option
  - Has extended its opportunities, across age and social groups
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>TBIs</th>
<th>All visits for sports and recreation-related injuries</th>
<th>% of all visits for TBIs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.†</td>
<td>Rate</td>
<td>95% CI</td>
</tr>
<tr>
<td>Age group (yrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤4</td>
<td>14,406</td>
<td>71</td>
<td>(48--93)</td>
</tr>
<tr>
<td>5--9</td>
<td>36,756</td>
<td>184</td>
<td>(136--231)</td>
</tr>
<tr>
<td>10--14</td>
<td>60,272</td>
<td>291</td>
<td>(226--357)</td>
</tr>
<tr>
<td>15--19</td>
<td>61,851</td>
<td>294</td>
<td>(226--361)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>122,970</td>
<td>292</td>
<td>(225--360)</td>
</tr>
<tr>
<td>Female</td>
<td>50,310</td>
<td>126</td>
<td>(96--155)</td>
</tr>
<tr>
<td>Sex/Rank</td>
<td>Age group (yrs)</td>
<td>5-9 No. (%)</td>
<td>10-14 No. (%)</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td>≤4 No. (%)</td>
<td>3,187 (35.3*)</td>
<td>8,988 (20.7)</td>
</tr>
<tr>
<td>Male</td>
<td>Bicycling</td>
<td>5,997 (23.6)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Playground</td>
<td>8,302 (19.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4,377 (9.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>20,285 (16.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>9,568 (7.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>9,372 (7.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>460 (5.1)</td>
<td>1,657 (6.5)</td>
<td>3,061 (7.0)</td>
</tr>
<tr>
<td>Other</td>
<td>2,680 (29.7)</td>
<td>9,558 (37.7)</td>
<td>16,476 (37.9)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9,020</td>
<td>25,362</td>
</tr>
<tr>
<td>Rate† (95% CI)</td>
<td>86 (61--112)</td>
<td>248 (182--313)</td>
<td>410 (316--504)</td>
</tr>
</tbody>
</table>

Overview

1. Definition, Pathophysiology and classification of traumatic brain injury (TBI)

2. Update on Diagnosis, Management and Outcome of Traumatic brain injury

3. Special consideration of Sports related TBI
Clinical Definition:

- Concussion
- Contusion (hemorrhage and/or edema)
- Contrecoup injury (hemorrhage and/or edema opposite to impact)
- Diffuse axonal Injury DAI (rotational acceleration/deceleration: hemorrhagic foci and microscopic evidence of axonal „damage“)

- Closed head injury vs. Open head injury
TBI – Classification

GCS based (mild 14-15, moderate 9-13, severe ≤ 8):

**BUT** Stein et al. 1996 in *Neurotrauma*:

- Minimal _ GCS =15, NO LOC, No amnesia
- Mild_GCS=15 + LOC < 5 min and/or impaired alertness or memory
- Moderate_GCS 9-13 or LOC > 5 min and/or focal neurological deficit
- Severe_GCS 5-8
- Critical_GCS 3-4

**Why classification?**

- 60% of severe TBI has associated injuries
- Outcome assessment

---

### Table 1: THE GLASGOW COMA SCALE AND SCORE

<table>
<thead>
<tr>
<th>Feature</th>
<th>Scale Responses</th>
<th>Score Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneous</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>To speech</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Verbal response</td>
<td>Oriented</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Confused conversation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Words (inappropriate)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sounds (incomprehensible)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Best motor response</td>
<td>Obey commands</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Localize pain</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Flexion – Normal</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>– Abnormal</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extend</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>

**TOTAL COMA SCORE** 3/15 – 15/15

---

### Table 1. Glasgow Coma Scale Modified For Pediatric Patients

<table>
<thead>
<tr>
<th>Eye Opening Response</th>
<th>&lt; 1 year</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spontaneous</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>To shout</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>To pain</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Verbal Response</td>
<td>0 to 2 years</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Elicits, coos approximately</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cries but is incoherent</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Persistent crying or screaming in pain</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Grunts or moans to pain</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Motor Response</td>
<td>&lt; 1 year</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Spontaneous</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Localizes pain</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Withdraws to pain</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Abnormal flexion to pain (dexterbrate)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Abnormal extension to pain (dexterbrate)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
TBI - Pathophysiology

**IMPACT Damage**

Contusion, lacerations, bone fragmentation, DAI

**SECONDARY Damage**

ICP

- Ischemia
- Hypoxemia

- CytoToxic Metabolic brain damage

Malignant cerebral edema: „Loss of cerebrovascular autoregulation“
Diagnosis

CT scan (Impact Damage)

Skull fractures
Hemorrhagic contusions
Epidural Hematomas
Subdural Hematomas
MRIs and TBI

Diagnosis of DAI and Secondary Damage

- Gradient-echo sequences are particularly useful in revealing the paramagnetic effects of petechial hemorrhages
- Eval of brain stem injury
- “Prognosis” of coma
Management : Neurocritical care

Management and Control of Intracranial pressure!

**Goal** CPP (PED) should be maintained ≥ 60 mmHg (CPP= MAP-ICP)

- Measurement of ICP:
  - GCS <8 and either abnormal admitting head CT or normal CT but risk factors (age > 40, SBP < 90mmHg, decerebrate or decorticate exam)
  - ICP Monitoring vs. External ventricular drain

- Neurocritical care of ICP
  - Physical measures (EOB 35 to 40 Degree)
  - Sedation and Paralysis
  - Ventilation (pCO2 30-35 mmHg)
  - Osmotic therapy (hypertonic saline, Mannitol)
  - Drain CSF
  - AED’s
  - Second tier (High-dose babiturate, Hypothermia, Hyperventilation)
Management: Neurosurgery

Management of uncontrolled ICP ("second tier")

- Evacuation of Hematoma or Contusion w/wo lobectomy
- Decompressive Craniectomy
Outcome and Impact of TBI

Predictors of outcome:
Initial GCS and associated injuries that accelerate brain ischemia!

Traditional Outcome assessment: GOS

Contemporary outcome assessment:
- Cognition
- Imaging
- Long-term outcome

Special Considerations of Sports related TBI
Outcome of TBI

Predictors of outcome:

- Severity of injury (GCS motor score)
- Type and extent of injury (Subdural hematoma, Diffuse injury + focal lesions, additional systemic injuries)
- Age younger than 5 years (in severe TBI, "vulnerable stage", "injury to a developing brain with loss of "adaptive function")
- Adverse family environment and psychosocial elements (preinjury behaviour, family environment, family economic status)

Outcome of TBI

Traditional Outcome assessment:

GOS and intellectual ability

<table>
<thead>
<tr>
<th>GCS* Severity</th>
<th>Glasgow Outcome Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Death</td>
</tr>
<tr>
<td>Severe[^3-8]</td>
<td>67</td>
</tr>
<tr>
<td>Moderate[^9-12]</td>
<td>17</td>
</tr>
<tr>
<td>Mild[^13-15]</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
</tr>
</tbody>
</table>

*GCS: Glasgow coma scale
Outcome of TBI

Comtemporary outcome assessment:

**Cognition** in the domains of explicit memory and learning, attention, executive functions (planning, self-regulation and problem solving) and organization and processing of narrative discourse and slowing of motor processing persist despite apparent recovery in intellectual ability.

**LONG-TERM**
- Beyond 2 years!
- Behavioural problems, emotional and personality changes do not stabilize after the usual 2 years of recovery and seem more important than intellectual disability.
- New deficits as the child matures and further decline in adulthood ("academic delays" and physiological effects of ageing).
- Only 23% of pre-school injuries work full time (Koskineniemi M et al., Arch Pediatr Adolesc Med 1995;149:249-254).
The following 20 sports/recreational activities represent the categories contributing to the highest number of estimated head injuries treated in U.S. hospital emergency rooms in 2009.

Cycling: 85,389
Football: 46,948
Baseball and Softball: 38,394
Basketball: 34,692
Powered Recreational Vehicles (ATVs, Dune Buggies, Go-Carts, Mini bikes, Off-road): 26,606
Soccer: 24,184
Skateboards/Scooters: 23,114
Fitness/Exercise/Health Club: 18,012
Winter Sports (Skiing, Sledding, Snowboarding, Snowmobiling): 16,948
Horseback Riding: 14,466
Gymnastics/Dance/Cheerleading: 10,223
Golf: 10,035
Hockey: 8,145
Other Ball Sports and Balls, Unspecified: 6,883
Trampolines: 5,919
Rugby/Lacrosse: 5,794
Roller and Inline Skating: 3,320
Ice Skating: 4,608

The top 10 sports-related head-injury categories among children ages 14 and younger:

Cycling: 40,272
Football: 21,878
Baseball and Softball: 18,246
Basketball: 14,952
Skateboards/Scooters: 14,783
Water Sports: 12,843
Soccer: 8,392
Powered Recreational Vehicles: 6,818
Winter Sports: 6,750
Trampolines: 5,025

“sports related traumatic brain injury children” = PUBMED (n=127) Lit. mainly about concussion
Sports and TBI other than concussion

Pediatric trauma in the Austrian Alps: the epidemiology of sport-related injuries in helicopter emergency medical service.

Selig HF, Hüpfl M, Trimmel H, Voelckel WG, Nagele P.

Source
Department of Anesthesiology and General Intensive Care and Pain Therapy, Medical University of Vienna, Vienna, Austria.
harald.se@gmx.at

Abstract
BACKGROUND/PURPOSE:
We aimed to examine the epidemiological characteristics and injury patterns of pediatric trauma in helicopter emergency medical service (HEMS) caused by sports/outdoor activities in alpine environment.

METHODS:
This retrospective cohort study analyzed 912 primary HEMS missions for pediatric trauma (0-14 years of age) in Austrian Alps between 1 January 2006 and 30 June 2007. Children were stratified by age into toddlers (3-5 years), children in early (6-9 years), and late school age (10-14 years).

RESULTS:
The majority of pediatric sports-related trauma in alpine environment was caused by skiing (82.1%; n=749). Pediatric patients were predominately in late school age and boys (72.8%, n=664 and 61.0%, n=556, respectively) and a minority (16.0%, n=146) was severely injured. Overall, fracture (47.0%, n=429), contusion (17.9%, n=163), and traumatic brain injury (17.0%, n=155) were the most common prehospital diagnoses. The most frequent pattern of injury was related to the head/face and spine (36.3%, n=331).

CONCLUSIONS:
The knowledge about epidemiological characteristics of HEMS use for injured children in alpine environment may be essential for training requirements of HEMS crews and operational considerations of HEMS providers. The incidence of head and spinal injuries requires support for initiatives to promote helmet wear and appropriate risk behavior amongst skiers and snowboarders.
Sledding injuries in US:


Howell CA, Nelson NG, McKenzie LB.
Source Center for Injury Research and Policy, Research Institute at Nationwide Children's Hospital, Department of Pediatrics, College of Medicine, Ohio State University, 700 Children's Dr, Columbus, OH 43205, USA.

Abstract
OBJECTIVES: The objectives were to examine comprehensively the patterns and to estimate the rates of sledding-related injuries among children and adolescents treated in US emergency departments between 1997 and 2007.

METHODS: Through the use of the National Electronic Injury Surveillance System database, cases of sledding-related injuries were selected by using diagnosis codes for sleds. Sample weights were used to calculate national estimates. US Census Bureau data were used to calculate injury rates per 100,000 individuals<or=19 years of age. Computation of odds ratios with 95% confidence intervals was performed.

RESULTS: From 1997 through 2007 an estimated 229 023 patients<or=19 years of age were treated for sledding-related injuries in US emergency departments, with an average of 20,820 cases per year. Children 10 to 14 years of age sustained 42.5% of sledding-related injuries, and boys represented 59.8% of all cases. The most frequent injury diagnoses were fractures (26.3%), followed by contusions and abrasions (25.0%). The head was the most commonly injured body part (34.1%), and injuries to the head were twice as likely to occur during collisions as through other mechanisms. Traumatic brain injuries were more likely to occur with snow tubes than with other sled types. A total of 4.1% of all cases required hospitalization.

CONCLUSIONS: More research on the prevention of sledding-related injuries is warranted, particularly regarding the impact of helmets in reducing injury rates. The use of sledding products that may reduce visibility (such as snow tubes) should be discouraged.
Bicycling in US

Pediatric head injuries and deaths from bicycling in the United States.
Sosin DM, Sacks JJ, Webb KW.
Source National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, Georgia 30341-3724, USA.

Abstract

OBJECTIVE: To estimate the potential benefit of increasing bicycle helmet use among children and adolescents in the United States.

DESIGN: All bicycle-related deaths (Multiple Cause-of-Death Public Use Data Tapes, 1989 through 1992) and bicycle-related injuries treated in sampled emergency departments (National Electronic Injury Surveillance System, 1989 through 1993) were used to calculate traumatic brain injury-associated death and head injury rates per 1,000,000 US residents. Preventable injuries and deaths were estimated by calculating the population-attributable risk of head injury due to nonuse of bicycle helmets.

PATIENTS: US residents aged 0 through 19 years who were injured or who died as a result of a bicycle crash.

RESULTS: An average of 247 traumatic brain injury deaths and 140,000 head injuries among children and adolescents younger than 20 years were related to bicycle crashes each year in the United States. As many as 184 deaths and 116,000 head injuries might have been prevented annually if these riders had worn helmets. An additional 19,000 mouth and chin injuries were treated each year. The youngest age groups had the highest proportions of both head and mouth injuries.

CONCLUSION: There continues to be a need to advocate for greater use of bicycle helmets, particularly among young children. Helmet design changes should be considered to prevent mouth injuries.
Special considerations on Sports and TBI

Mechanism:
Besides abundant data on concussion, only little data on non-concussion damage in sports related injury

✓ Multisystem injuries
✓ High Lethality
✓ High Impact Forces

Medical and Health care aspects:
- e.g. Europe (no insurance coverage for sports injuries...)

Social and Psychological aspects:
- „Life Loss from Leisure“
Aspects of Prevention and Rehabilitation

Further inquiry into the nature, prevalence, causes, and, in particular, sequelae of pediatric sports injuries is required.

In the interim, attention to proper technique, core and neuromuscular conditioning, and helmet use are important preventive measures; avoidance of overtraining and providing adequate rest for recovery are essential for pediatric and adolescent athletes.

1. Family and environment centered services provided by an interdisciplinary team (teaching of compensations strategies)

2. Individual centered strategies based on previous pattern of behaviour and socioeconomic status

3. **Role of Pharmakotherapy:** Amantadine hydrochloride (enhance dopamine projections to the frontal cortex) has shown improved outcome on executive function in pediatric TBI compared to standard treatment
Summary

Two main targets

- Prevention
- Restoration of brain function (e.g. Pharmacology)

ALL Interdisciplinary!
Ongoing research and **Neurosurgical potentials**

**Neurorestoration and neuroprotection!**

Cerebral transplantation of encapsulated mesenchymal **stem cells** improves cellular pathology after experimental traumatic brain injury.