The Acute Identification, Diagnosis, and Management of Children with Mild Traumatic Brain Injury

Recommendations from the Pediatric Mild Traumatic Brain Injury Guideline Work Group presented to the Centers for Disease Control and Prevention

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Background

Traumatic brain injury (TBI) is a leading cause of death and disability in the U.S. with many public health implications. Pediatric TBI accounts for 3,000 deaths, 29,000 hospitalizations, and 473,947 emergency department (ED) visits in the US annually in children less than 15 years of age. Falls cause 50% of these visits. At least 75% of all TBIs reported in the United States are classified as “mild” or “concussions.” Children are at risk for sustaining mild TBIs due to their developing coordination, changing head to body ratio, risk taking behaviors, and wide participation in sports and play. Forty percent of all patients diagnosed with concussion are children between the ages of 15-19 years old.

Though many pediatric head injuries go unreported, 720,000 children less than 19 years of age were diagnosed with concussion in US emergency departments from 2002-2006. Sixty-nine percent of these diagnoses were in males. Thirty percent of pediatric concussions were sports-related.
Mild TBI (mTBI) is one of the most common neurological disorders, but there is no universally accepted definition.\textsuperscript{10} The terms concussion, minor head injury, and mTBI are often used interchangeably throughout the scientific literature, but have different connotations to families, coaches, and medical providers. In several studies, an injury described as a concussion was considered less severe than one described as an mTBI and suggested that this may result in a premature return to activity.\textsuperscript{11} 12

For the purposes of this guideline, concussion and mTBI will be used interchangeably and defined according to the following CDC recommendations. The CDC currently defines mTBI as an injury to the head resulting from blunt trauma or translational forces in children with a GCS of 14 or greater with one or more of the following related symptoms: transient confusion, disorientation, impaired consciousness, amnesia, loss of consciousness less than 30 minutes, and neurological or neuropsychological dysfunction including headache.\textsuperscript{13}

Following mTBI, the brain's physiology is altered causing a variety of pathophysiological processes including metabolic dysregulation and cytotoxic edema.\textsuperscript{14} For most patients with mTBI these processes are believed to reverse after a period of recovery.\textsuperscript{15} 16 In a subset of patients, and via currently unclear processes, post-concussive symptoms persist past 2 weeks and continue for longer than 3 months. Such significant, long-term impairment affects an individual’s ability to function physically, cognitively, and psychologically.\textsuperscript{17} 18 19 It is estimated that 3.2 to 5 million people in the United States are living with the long-term consequences of TBI.\textsuperscript{20} 21 22

To help address this public health problem, Congress passed the Children’s Health Act of 2000 (Public Law 106-310) charging the CDC with compiling the latest science on this injury, creating a definition for mTBI, and determining best methods to quantify it’s incidence and prevalence.\textsuperscript{23} In response, CDC formed the Mild Traumatic Brain Injury Work Group, composed of experts in the field of brain injury, including those representing: the Society for Academic Emergency Medicine, the Brain Injury Association of America, the American Congress of Rehabilitation Medicine, the American Academy of Neurology, and the National Institute on Disability and Rehabilitation Research.\textsuperscript{24}

\textit{The Identification, Diagnosis, and Management of mTBI: Current Guidelines}
In 2008, the CDC and the American College of Emergency Physicians produced neuroimaging and decision-making guidelines for adults with mTBI in the acute setting.\textsuperscript{25} These guidelines apply to patients aged \textgeq16 years who have a non-penetrating brain injury and a GCS score 14 or greater. In 2012, a Canadian consensus guideline was published on managing patients’ mTBI
with persistent symptoms.\textsuperscript{26} Most recently, the American Academy of Neurology will publish an evidence-based guideline for adults and the pediatric population on the management of sports-related concussion in Spring 2013.\textsuperscript{27}

Though there have been landmark studies, including validated prediction rules, in the last 10 years regarding pediatric TBI, there are currently no existing evidence-based clinical guidelines in the United States regarding the best practices for the diagnosis and management of mTBI in children not specific to sports-related injury. Clinical guidance for health care professionals on identification, diagnosis, and management of pediatric mTBI will contribute to improving the health and safety of this vulnerable population.

**Pediatric Mild TBI Guideline Work Group**

To provide leadership in this area, CDC’s National Center for injury Prevention and Control’s (NCIPC) Board of Scientific Counselors established the Pediatric Mild TBI Guideline Work Group. This expert panel is charged with developing guidelines to address the identification, diagnosis, and management of acute mTBI among children. Comprised of leading experts in the field of TBI, the workgroup will create a multi-organizationally endorsed guideline within a 24 month timeframe. CDC medical officers and epidemiologists working in the field of TBI selected Work Group members. An initial list of potential Work Group members was collated based on a literature review to identify authors, or relevant literature and authors, or other TBI clinical practice guidelines. Expert nominations for the Work Group were obtained through recommendations by various medical and health organizations. Once the initial list was created, an online biography was obtained for each candidate and reviewed by the CDC selection staff. CDC staff rated each candidate as a high match, moderate match, or low match. The candidates were evaluated on the following criteria:

- Experience with TBI and pediatrics, as evidenced through biographies and publications obtained from literature searches.
- Fit with expertise selection criteria that will represent a cross-section of professional settings including clinical, research, health care systems, sports, and school environments with credentials and expertise in the following areas: pediatrics; family medicine; internal medicine; emergency medicine; neurology; neurosurgery; neuroimaging; neuropsychology; epidemiology; sports medicine; nursing; physician assistant practice; emergency medical services; physical therapy and rehabilitation; athletic training; school health; and content expertise in injury prevention, including motor vehicle safety, child maltreatment, falls safety, and sports safety.

The resulting list of Work Group members consists of 49 non-federal members and 7 federal representatives from the National Institutes of Health, Department of Education, Health Resources and Services Administration, Department of Defense, and the Consumer Product Safety Commission. Work Group members were required to attest to financial and intellectual conflict of interest.
Overall Objective of the Pediatric Mild TBI Guideline Work Group
The objective of the Pediatric Mild TBI Guideline Work Group is to establish evidence-based recommendations, using the existing literature, to address the lack of consensus on the acute diagnosis and treatment of mTBI in children aged 18 years and younger. The goal is to provide health care professionals, who care for children in primary care, outpatient specialty, inpatient and emergency care settings, with the latest science to guide the diagnosis and treatment of mTBI in children.

Although the definition of mTBI is an important and controversial issue, for the purposes of the guideline, CDC’s previously defined mTBI definition will be used. The mTBI definitions used in relevant studies identified by the systematic review will be reviewed, tracked, and summarized.

Selection of Clinical Questions
After presentation of an analytic framework and an introduction to the Patient-Intervention-Comparative intervention-Outcome (PICO) format for questions, Work Group members independently nominated questions for consideration. Candidate questions were collated and presented to the entire group. Using a modified Delphi process questions were anonymously ranked on a 9 point ordinal scale of importance over three rounds of voting. Facilitated discussions amongst Work Group members occurred between voting rounds. Through this process, the Work Group selected 6 clinical questions. The questions and a brief rationale for their selection are discussed below.

Clinical Questions and Rationale
Although evidence-based clinical decision rules have been recently published to guide the use of CT imaging to identify intracranial injury, challenges in the acute diagnosis of mTBI still exist.28 Advanced imaging techniques such as diffusion tensor imaging, MR spectroscopy, perfusion weighted imaging, and functional MRI have shown changes in patients with mTBI, though their utility in management and feasibility of use has yet to be examined. There is a need for more evidence regarding the reliability and validity of various tools and questionnaires to diagnose mTBI. To address these issues, the Work Group developed the first research question:

1. For children (18 years of age and younger) with suspected mild TBI, do specific tools as compared with a reference standard*, accurately diagnose mild TBI?

*Acceptable diagnostic reference standards for question 1 will not be pre-specified. We will track the reference standards used in the identified studies during the data extraction process. A clinical decision rule was recently published based on sign and symptom evaluation of more than 40,000 children with suspected mTBI.29 Despite the availability of such decision rules, confusion remains regarding how to best distinguish mild versus more significant TBI in acute care settings. Biomarker and imaging diagnostics for mTBI are reported in the literature and
continue to be researched. The decision to obtain head CT imaging following suspected mTBI remains a concern due to exposure to ionizing radiation. This led to the development of the next two questions:

2. For children (18 years of age and younger) presenting to the emergency department (or other acute care setting) with mild TBI, how often does routine head imaging* identify important intracranial injury#?

3. For children (18 years of age and younger) presenting to the emergency department (or other acute care setting) with mild TBI, which features identify patients at risk for important intracranial injury?

*Routine head imaging pertinent to questions 2 and 3 will include skull x-rays, CT and MRI. #Important craniocerebral abnormalities will be those that change acute treatment. For example, those abnormalities which prompt more prolonged emergency room observation, hospitalization or neurosurgical consultation (e.g., intracranial hemorrhage, depressed and basilar skull fractures). Subtle changes of unclear significance (e.g. changes on diffusion tensor MRI images) will not be considered for questions 2 and 3. Such imaging changes will be considered as potential prognostic features in questions 4 and 5.

A significant subset of children with mTBI develop pronounced and prolonged symptoms prompting the need to identify factors that contribute to their course of recovery. A number of factors have previously been identified as potential predictors of recovery following mTBI including: age at injury, individual characteristics including genomics and medical history, social-demographic and family characteristics, the mechanism of the insult, repeat injury, acute medical management and follow-up. The need to identify evidence-based predictors of protracted recovery led to development of the fourth and fifth questions:

4. For children (18 years of age and younger) with mild TBI, what factors* identify patients at increased risk for ongoing impairment, more severe-symptoms, or delayed recovery?

5. For children (18 years of age and younger) with mild TBI, which factors identify patients at increased risk of long-term# (>1 year) sequelae?

*Any feature of potential prognostic importance will be considered relevant to questions 3, 4 and 5. All potential features cannot be exhaustively anticipated before reviewing the literature. Potential features include those already listed in the questions and will also include the mechanism of injury and the timing of the imaging after injury.

#The distinction in timing (> 1 year) of post-injury sequelae between questions 4 and 5 is somewhat arbitrary. The literature relevant to both of these questions will be identified with a single search. The timing of the sequelae described from each identified study will be tracked during the data extraction process. A reasonable distinction between short and long term mTBI consequences will be made based upon the descriptions provided in the literature. At the protocol development stage, 1 year will be working distinction between short and long-term sequelae.
The emergency department and outpatient management of children with mTBI by primary and subspecialty clinicians is controversial. Expert recommendations for the treatment of mTBI have been published without extensive supporting research. Generally, supportive care, cognitive rest, and a step-wise return to play have been recommended. However, with growing subspecialty clinics, unique application of computerized neurocognitive testing, emerging research on novel therapies, and increasing concerns about potential iatrogenic effects of cognitive rest, further evaluation is required. This led to the development of the sixth and final question:

6. For children (18 years of age and younger) with mild TBI (with ongoing symptoms) which treatments* improve mild TBI-related outcomes?

*Any therapeutic modality will be considered pertinent to question 6.

**Guideline Development Methodology**

The systematic review and practice recommendations will be developed using the guideline development methods of the American Academy of Neurology. These methods have been designed to be compliant with the 2010 standards of the Institute of Medicine.

**Inclusion Criteria by Question number**

1. Studies of children (18 years of age and younger) with and without mTBI. A putative diagnostic test is performed and is compared to an mTBI reference standard in both populations.
2. Studies of children (18 years of age and younger) with mTBI evaluated in an emergency department or other acute care setting undergo head imaging. The proportion of patients with traumatic intracranial abnormalities is reported.
3. Studies of children (18 years of age and younger) with mTBI evaluated in an emergency department or other acute care setting with and without a putative risk factor. The proportion of patients with traumatic intracranial abnormalities are reported in both populations.
4. Studies of children (18 years of age and younger) with mTBI with and without a putative risk factor. The study measures the strength of association between the risk factor and symptom severity or duration.
5. Studies of children (18 years of age and younger) with mTBI with and without a putative risk factor. The study measures the strength of association between the risk factor and long-term (>1 year) sequelae.
6. Studies of children (18 years of age and younger) with mTBI who receive and do not receive a treatment (randomization to treatment groups not required). The study measures the association between treatment and mTBI-related outcomes.

**Literature Search Strategy**

The databases to be searched include MEDLINE (via PubMed), EMBASE, ERIC, SPORTDISCUS and CINAHL. All searches will be limited by date from January 1, 1990 to the date of the search. All languages will be included. Publication types excluded were: comments,
editorials, patient education handouts, newspaper articles, biographies, autobiographies, and case reports. In addition to a review of computerized bibliographic databases, panel members will review the bibliographies of identified review articles.

The search strategies were developed and refined by performing test searches of MEDLINE (via PubMed). The sensitivity of the search was determined using a list of relevant index articles independently identified by the expert panel. The specificity of the searches was determined by reviewing a randomly selected subset of the citations identified by the test searches. The finalized searches had a sensitivity of 100% relative to the index articles. The final search strategies to be used according to question are enumerated in Appendix A. Complete search strategies for all databases searched are available at the following link [http://www.aan.com/globals/axon/assets/10405.pdf](http://www.aan.com/globals/axon/assets/10405.pdf).

**Review Process of completed guideline**
Comments will be specifically sought from the following organizations: American Academy of Pediatrics; American Academy of Family Physicians; American Academy of Neurology; American Academy of Neurological Surgeons; American Academy of Physical Medicine and Rehabilitation; American Physical Therapy Association; American College of Emergency Physicians; American College of Sports Medicine; American College of Surgeons; American Medical Association; American Medical Society for Sports Medicine; American Orthopedic Society for Sports Medicine; National Academy for Neuropsychology; National Athletic Trainers Association; Society for Physicians Assistants in Pediatrics; Child Neurology Society; Emergency Nurses Association; National Association of School Nurses; American Nursing Association; American College of Physicians; National Association of School Psychologists; National Association of EMS Physicians; and National Association of State EMS Officials.

**Guideline publication**
The guideline will be submitted for publication by June of 2014.

**Anticipated timeline**
*Review of abstracts*: Completed by January 31, 2013
*Screening of full-text articles*: Completed by March 15, 2013
*Review of full-text articles and data extraction*: May 3, 2013
*Evidence tables*: Completed by June 7, 2013
*First draft of systematic review*: Completed by September 20, 2013
*Preparation of draft recommendations and rationales*: Completed by October 18, 2013
*Modified Delphi process to assign levels of obligation*: Completed by November 1, 2013
*Final draft of guideline for public comment*: Completed by February 3, 2014
*Revisions of document in response to comments*: Completed by March 7, 2014
SELECTION OF CLINICAL QUESTIONS

RATIONALE ONE

RATIONALE TWO

RATIONALE THREE

RATIONALE FOUR
RATIONALE FIVE
EFNS paper
WHO collaborating centre paper

RATIONALE SIX

GUIDELINE DEVELOPMENT METHODOLOGY

APPENDIX A.
Question 1: For children (18 years of age and younger) with suspected mTBI, do specific tools as compared with a reference standard, accurately diagnose mTBI?
This search included a POPULATION component and a DIAGNOSIS component. In Boolean terms, these components were combined as follows:

POPULATION AND DIAGNOSIS
POPULATION: CHILDREN, ADOLESCENTS, PEDIATRIC

OR


OR

MINIMAL TRAUMATIC BRAIN INJUR*[TIAB] OR MINIMAL TBI[TIAB]

NOT

(ANIMALS[MH] NOT (ANIMALS[MH] AND HUMAN*[MH]))

NOT


NOT


DIAGNOSIS:
Questions 2 and 3: For children (18 years of age and younger) presenting to the emergency department (other acute care setting) with mTBI, how often does routine head imaging identify important intracranial injury? Which features identify patients at risk for important intracranial injury?
This search included a larger (more results) POPULATION component than Question 1. It also included a component to identify emergency or other acute care settings and components for IMAGING and for INTRACRANIAL INJURY. In Boolean terms, the components were combined as follows:

(POPULATION AND ACUTE CARE SETTING) AND (IMAGING OR INTRACRANIAL INJURY)

POPULATION:
NOT

(ANIMALS[MH] NOT (ANIMALS[MH] AND HUMAN*[MH]))
NOT

NOT


ACUTE CARE SETTING:

IMAGING:


INTRACRANIAL INJURY:

Questions 4 and 5: For children (18 years of age and younger) with mTBI, what factors identify patients at increased risk for ongoing impairment, more-severe symptoms, or delayed recovery? Which factors identify patients at increased risk of long-term (> 1 year) sequelae?

This search included the same POPULATION component as Question 1. In addition it included components for PROGNOSIS and for RISK FACTORS FOR SEQUELAE. In Boolean terms, they were combined as follows:

POPULATION AND (PROGNOSIS OR RISK FACTORS FOR SEQUELAE)

POPULATION:


OR


OR


OR

MINIMAL TRAUMATIC BRAIN INJUR*[TIAB] OR MINIMAL TBI[TIAB]

NOT

(ANIMALS[MH] NOT (ANIMALS[MH] AND HUMAN*[MH]))

NOT

NOT


PROGNOSIS:


RISK FACTORS FOR SEQUELAE:
Question 6: For children (18 years of age and younger) with mTBI (with ongoing symptoms) which treatments improve mTBI-related outcomes?

This search included the same POPULATION component as Question 1. It also included a TREATMENT component and a component for the concept of ONGOING SYMPTOMS. In Boolean terms, the components were combined as follows:

**POPULATION AND ONGOING SYMPTOMS AND TREATMENTS**

**POPULATION:**


OR


OR


OR

MINIMAL TRAUMATIC BRAIN INJUR*[TIAB] OR MINIMAL TBI[TIAB]

NOT

(ANIMALS[MH] NOT (ANIMALS[MH] AND HUMAN*[MH]))

NOT


NOT

ONGOING SYMPTOMS:


TREATMENTS:


27 http://www.aan.com/go/practice/concussion
