2013

Preschool Children with Head Injury: Comparing Injury Severity Measures And Clinical Care

JoAnne M. Youngblut
Nicole Wertheim College of Nursing and Health Sciences, Florida International University, youngblu@fiu.edu

Carmen Caicedo
Nicole Wertheim College of Nursing and Health Sciences, Florida International University, ccaicedo@fiu.edu

Dorothy Brooten
Nicole Wertheim College of Nursing and Health Sciences, Florida International University, brooten@fiu.edu

Published in final edited form as:
Pediatr Nurs. 2013 ; 39(6): 290–298.

Preschool Children with Head Injury: Comparing Injury Severity Measures And Clinical Care

JoAnne M. Youngblut, PhD, RN, FAAN,
Professor, Florida International University, Nicole Wertheim College of Nursing & Health Sciences, Miami, FL

Carmen Caicedo, PhD, RN, and
Assistant Professor, Florida International University, Nicole Wertheim College of Nursing & Health Sciences, Miami, FL

Dorothy Brooten, PhD, RN, FAAN
Professor, Florida International University, Nicole Wertheim College of Nursing & Health Sciences, Miami, FL

Abstract

The purpose of this study was to compare child, hospital course, and discharge characteristics by admitting unit, injury type, head Abbreviated Injury Scale (AIS), and Glasgow Coma Scale (GCS), and test congruence of AIS and GCS categories. Chart data were collected from seven hospitals on 183 preschool children with head injury (90 admitted to PICU, 93 to general care unit). Injury events included falls (n = 89, 49%), hit by car (n = 35, 19%), motor vehicle crashes (n = 26, 14%), bicycle crashes (n = 12, 7%), and blunt traumas (n = 21, 11%). Most children (68%) had head injuries only, 20% had other fractures, 5% had organ damage, and 7% had all three. Injury severity was measured by head AIS and GCS scores. Treatments and procedures included tubes/lines, blood/blood products, and medications. Children with head injuries only had fewer hospital days, less severe head injuries, and near normal GCS scores. They were less likely to have tubes/lines and medications. Children were discharged with medications (61%) and medical equipment (14%). Five children were discharged to long-term care facilities, and five were discharged to rehabilitation facilities. Concordance of head AIS and GCS categories occurred for only 50 (28%) children. Although the GCS is the gold standard for identifying changes in neurological status, it was not as helpful in representing hospital care. Head AIS injury categories clustered children in more homogeneous groups and better represented hospital care. Head AIS categories are better indicators of injury severity and care provided than GCS. Head injury AIS score may be an important addition to GCS for guiding care.

Head injury is the leading cause of death and disability in children (Walker et al., 2009). Annually, it accounts for over 500,000 emergency department visits, 95,000 hospital admissions, hospital costs exceeding $2 billion, and 3,000 deaths (Faul, Wald, & Coronado, 2010). More than 80% of these children suffer mild head injuries, but 6% die from their head injury (Bowman, Bird, Aitken, & Tilford, 2008; Goldberg et al., 2011). Parents frequently ask health care providers what to expect during their child's clinical course. Treatment of children's head injury remains difficult, with no single treatment or defined best practice to improve outcomes dramatically. The result is no universally agreed upon category of "trivial" head injury for which there is no risk of a major intracranial complication (Dunning, Daly, Lomas, Batchelor, & Mackway-Jones, 2006).

Adelson et al. (2003) reported the importance of aggressive resuscitation and intensive monitoring of both adults and children with traumatic brain injury (TBI). However, debates continue about the best and necessary monitoring and medical treatment modalities for TBI in children (Adelson et al., 2003). For children with mild closed head injury with brief loss of consciousness and amnesia, headache, lethargy, nausea, or vomiting, the American Academy of Pediatrics (AAP) recommended observation with computerized tomography (CT) scanning. However, some children with mild but clinically significant TBI will not show symptoms, rendering physical and neurologic examination less useful. This has led some physicians to recommend CT scans for mild TBI accompanied by brief loss of consciousness (AAP, 1999). Standard trauma guidelines have recommended that patients with major head injuries receive aggressive cardiopulmonary and hemodynamic resuscitation (Adelson et al., 2003) to reduce the incidence of secondary brain injuries caused by hypoxia, hypotension, and increased intracranial pressure (ICP). If the ICP cannot be controlled with medical management (narcotics, sedatives, paralytic agents, and/or osmotic diuretics), invasive procedures or surgery may be necessary (Adelson et al., 2003).

Early recognition of factors predicting outcome can contribute to more selective management of the more severe injuries. Trauma scoring systems (physiologic, anatomical, and combined systems) have been developed and refined over the past 20 years. The two most common scoring systems are the head Abbreviated Injury Scale (AIS) (Association for Advancement of Automotive Medicine [AAAM], 1990) and the Glasgow Coma Scale (GCS) (Teasdale & Jennett, 1974). Using and interpreting trauma scoring systems accurately together with the use of specific guidelines for treatment can contribute significantly to improving the outcome for preschool children with TBI (Grinkeviciute et al., 2007). For preschool children with head trauma, the congruence of classification on these two scales and differences in care are not known.

The aims of this study of pre-school children with unintentional TBI are to compare a) hospital course by admitting unit and types of injuries, b) classification of head injury severity between the head AIS and the GCS, and c) head AIS groups and GCS groups on the admission unit, types of injuries, and kinds of treatments. Chart data for this study were collected as part of a larger, longitudinal study of child, parent, and family functioning in the first year after the preschool child's hospitalization for head injury (Youngblut & Brooten, 2006, 2008; Youngblut, Brooten, & Kuluz, 2005).

Materials and Methods

Setting and Procedure

Hospital records of 183 preschool children (ages 36 through 83 months) who suffered a head injury were reviewed after parental consent. Children were hospitalized in one of seven tertiary care centers, including three free-standing children's hospitals. Admission to the pediatric intensive care unit (PICU) versus a general care unit (GCU) was decided by the admitting physicians (not involved in the study) and hospital policy. Institutional Review Board approvals were obtained from the appropriate universities and hospitals.

For this research, head injury was defined as an injury event where a blow to the head was probable with at least one physical finding suggesting head trauma, including symptoms of head injury in children: loss of consciousness no matter how brief, emesis, drowsiness, seizures, neurological deficits, cerebrospinal fluid or bloody discharge from the ears or nose, or a positive CT scan or skull X-ray. To be eligible, the injured child was a) free from chronic illnesses other than asthma, b) not previously hospitalized other than at birth, and c) without severe pre-existing cognitive deficits. For purposes of the larger study, children had to be living with at least one biological or adoptive parent before the injury and expected to survive. Parents had to understand spoken English. Exclusion criteria necessary for the larger study were a) injury suspected to be due to child abuse, b) child meeting or being evaluated with brain death criteria, c) parent(s) hospitalized concurrently with major injury, or d) death of parent(s) in the injury event.

At 24 to 48 hours after the child's hospital admission, a research assistant approached the parents to explain the study, ascertain eligibility, answer questions, and obtain written consent for participation in the longitudinal study and access to the child's hospital record. Demographic data were collected by parent interview. Data on cause and extent of injury, treatments and procedures, measures of injury severity, and admitting unit (PICU or GCU) were collected through review of the child's hospital chart by a registered nurse research assistant.

Instruments

Injury severity was measured through hospital record review with the Abbreviated Injury Scale (AIS) and the Glasgow Coma Scale (GCS). Severity of the anatomical injuries for the AIS was determined with reports of clinically indicated procedures (X-ray, CT, magnetic resonance imaging [MRI], laboratory, operative) and chart notes recorded at the time of care by emergency room staff, emergency medical service providers (when available), and admitting physicians and nurses. Most GCS scores were recorded in the chart as part of the clinical care.

The AIS classifies severity of individual anatomical injuries by body regions, and therefore, does not change over time. Severity of injury in six body regions (head/neck, face, chest, abdomen, extremities/pelvic girdle, and external) is scored from one to six. The Injury Severity Scale (ISS) total score is calculated by summing the squares of the highest AIS code in the three body regions with the most severe injury. Severity scores for the AIS for a specific body region and the total ISS score are categorized as minor/mild, moderate, serious, severe, critical, and major/grave (AAAM, 1990). Children with "major/grave" injuries rarely survive, making them ineligible for the larger study. The severe and critical categories were combined because of the small number in each category. For this analysis, children's head AIS scores were used to characterize the severity of head injury from mild to severe/critical. Three children's head injuries were not scored because of lack of sufficient specific information in the chart to make a determination.

The GCS measures level of consciousness based on the child's best responses in three areas: eye opening, verbal response, and motor response. Response ratings range from *one* "no response" to *four* "spontaneous" for eye opening, from *one* "no response" to *five* "oriented, appropriate" for verbal responses, and from *one* "no response" to *six* "obeys commands" for motor response. Word descriptors are provided for each number. Total summative scores are classified as mild (13–15), moderate (9–12), and severe (3–8) (Teasdale & Jennett, 1974). The lowest GCS score for the first 24 hours after hospital admission and the GCS at discharge were collected. Data for GCS scoring were not available for the first 24 hours after injury for five children and at discharge, for 11 children.

Treatments/Procedures

Treatments and procedures include a) diagnostic procedures – MRI, CT scan, or skull X-ray; b) tubes and lines – ICP, arterial pressure, or central venous pressure monitoring lines; endotracheal tube; urinary catheter; nasogastric tube; chest tube; or wound drain; c) blood or blood products; d) medications – mannitol, pentobarbital, phenobarbital, phenytoin, and pancuronium bromide; and e) surgery.

Other data collected from the child's hospital record included the injury event, admitting unit (PICU vs. GCU), admitting physician's appraisal of the child's overall condition, other injuries, need for equipment and medications, existence of a new chronic condition, and discharge disposition.

Data Analysis

Description of the sample was conducted with frequencies and descriptive statistics. Comparisons of categorical variables were conducted with Chi Square (χ^2) analysis and of interval/ratio variables with one-way analysis of variance (ANOVA) with Scheffe tests for post-hoc comparisons.

Results

Sample Description

The sample consists of 183 preschoolers, 104 boys and 79 girls, with an average age of 59.8 months (*SD* = 14.79). Race/ethnicity identified by the parents was 56% White, 30% Black, 13% Hispanic, and 1% Asian. Causes of head injuries were falls (*n* = 89, 49%), hit by a car as a pedestrian or while riding a bicycle (*n* = 35, 19%), motor vehicle crash (*n* = 26, 14%), bicycle crash (*n* = 12, 7%), and other blunt trauma events (*n* = 21, 11%). Of the 116 (63%) children treated at the scene of the injury, 104 (89.7%) were treated by emergency personnel, 10 (8.6%) by bystanders, and 2 (1.7%) by a parent. Most of the children (*n* = 130, 71%) were admitted from the hospital's emergency department, and 46 (25%) were transferred from another hospital. Compared to those admitted directly to the tertiary care hospital, children who were transferred from another hospital were significantly more likely to have experienced a bicycle crash (without involvement of a motor vehicle) or another type of blunt trauma (χ^2 = 11.3, p = 0.02). The two groups did not differ significantly on gender, admission condition or unit, types of injuries, head AIS category, GCS category at 24 hours or at discharge, treatments, or discharge disposition. Condition on admission was "good" or "fair" for 31 children (17%), "stable" for 100 children (54%), "guarded" for 36 children (20%), and "poor" or "grave" for 11 children (6%). Condition was not indicated for five children. Most children (68%) had head injuries only, 20% had other fractures (including one spinal cord injury), 5% had organ damage, and 7% had all three. Injured organs were the lung for 12 children, the spleen for six children, the liver for six children, the kidney for four children, the gastrointestinal tract for four children, and the heart for two children. Total length of hospital stay ranged from one to 41 days (*M* = 3.2 days, *SD* = 4.98). One (0.5%) child was transferred back to the referring hospital, five (2.8%) to a long-term care facility, and five (2.8%) to a rehabilitation facility. All children but one ultimately were discharged home.

PICU versus GCU Groups

The group of children initially admitted to the PICU (*n* = 90, 49.2%) and the group initially admitted to the GCU (*n* = 93, 50.8%) did not differ in gender, age, or having received treatment at the scene. On admission, 92 (99%) children in the GCU group and 42 (47%) in the PICU group were in good to stable condition. More than half (*n* = 48, 53%) of the PICU group were admitted in guarded, poor, or grave condition. Children in the PICU group had significantly higher ISS and head AIS scores, lower GCS scores, and longer hospital stays than children in the GCU group. Children in the PICU group spent an average of 3.2 days (*SD* = 5.50) in the PICU and 1.9 days (*SD* = 2.62) in the GCU. Children in the PICU group were more likely to experience a temporary loss of consciousness after the injury event, need surgery, and have a urinary catheter and/or a gastric tube than the GCU group. Almost half (*n* = 43, 48%) of the PICU children had endotracheal tubes, 20 (22%) had arterial lines, and 11 (12%) received transfusion of packed red blood cells, fresh frozen plasma, and/or platelets. Fewer than 10 children had a chest tube, central line, ICP line, or wound drains. None of the children in the GCU group experienced any of these treatments or procedures. All but one child who received phenytoin and all children who received phenobarbital, pentobarbital, mannitol/urea, or pancuronium bromide were in the PICU group. All children admitted to the GCU but only 79 (88%) of those admitted to the PICU were discharged home directly. Children in the PICU group were more likely to be discharged with a new chronic condition and medications than children in the GCU group. Thus, admitting unit clearly differentiated between children with less serious injuries and those with very serious injuries requiring aggressive care.

Types of injuries were categorized into four groups: head injury only (*n* = 123, 65%), head injury plus other fractures (*n* = 37, 20%), head injury plus organ damage (*n* = 9, 5%), and head injury plus both other fractures and organ damage (*n* = 12, 6%) as shown in Table 1. Children with TBI but no organ damage were significantly more likely to be admitted in good, fair, or stable condition (*n* = 95, 77%), while children with organ damage were more likely to be in guarded, poor, or grave condition (*n* = 13, 62%). Organ damage was more common when the injury event involved a motor vehicle regardless of whether the child was a passenger in the vehicle, a pedestrian, or riding a bicycle. Children with TBI only were less likely to be admitted to the PICU and had the shortest mean length of hospital stay and the lowest injury severity (low head AIS, high GCS in the first 24 hours). Fewer of them had surgery, tubes and lines, and medications. All but two with TBI only were discharged home.

Few children with TBI only were discharged with a new chronic condition or equipment, but 67 (55%) were discharged on medications.

Children with TBI and organ damage, with or without other fractures, were most likely to be admitted to the PICU and to have urinary catheters, gastric tubes, endotracheal tubes, chest tubes, arterial pressure lines, central lines, and/or ICP monitors. More of the children with TBI and organ damage received the medications in Table 1. More than half were discharged home with a new chronic condition and medications. Children with all three (TBI, other fractures, and organ damage) had the longest mean hospital stay, the highest ISS and head AIS scores, and the lowest GCS scores. They were most likely to have had surgery, a temporary loss of consciousness, a period of coma, and transfusion of blood products. More than half of these children were discharged home with a new chronic condition (*n* = 7, 58%), equipment (*n* = 7, 58%) and/or medications (*n* = 9, 75%).

Comparison of Head AIS And GCS Categories

Both the head AIS and the GCS were used to indicate severity of head injury. Only 50 (28.4%) children were in the same injury severity category on both the AIS head and the GCS (bold typeface in Table 2). Head AIS groups and GCS groups were least concordant for the mild categories. Of the 137 children in the GCS mild group, head AIS was mild for only 23 (17%) children, moderate for 62 (45%) children, serious for 26 (19%) children, and severe/critical for 26 (19%) children. For the GCS and AIS mild groups, 118 (86%) and 22 (92%), respectively, were admitted in good, fair, or stable condition. Most of the GCS severe group (*n* = 22, 87.5%) and 40 (49%) of the AIS serious and severe/critical groups were admitted in guarded, poor, or grave condition.

Head AIS Groups

The head AIS mild group had the lowest total ISS score and the highest GCS score and were least likely to experience a temporary loss of consciousness, PICU admission, surgery, a urinary catheter, gastric tube, or endotracheal tube (see Table 3). All were discharged home, 48% with medications, 20% with a new chronic condition, and 12% with equipment. As expected, GCS scores decreased with increasing head injury severity. Total ISS score, length of hospital stay, and proportion of children with temporary loss of consciousness, coma, PICU admission, tubes, lines, and hospital medications increased as the head AIS category got more severe.

The head AIS serious group had longer lengths of stay, higher total ISS scores, lower GCS scores, and more children in the PICU than the moderate group. More children in the serious group had urinary, gastric, and endotracheal tubes; arterial, central, and ICP lines; and medications than the moderate group. The moderate and serious groups were similar in their proportions of children with temporary loss of consciousness, surgery, and a new chronic condition, medications, and equipment at discharge. Two of the serious, but none of the moderate, were discharged to a rehabilitation or long-term care facility.

The head AIS severe/critical group had the longest lengths of stay, highest total ISS scores, lowest GCS scores, and the greatest proportions of children with a period of coma, PICU admission, surgery, all lines and tubes, medications, and blood transfusion. Fewer children from the severe/critical group were discharged home, and more were discharged with a chronic condition than all other groups. However, the proportions of children in the severe/critical group discharged with medication and/or equipment did not differ from the other groups.

GCS Groups

The GCS severe group had longer lengths of stay and higher total ISS scores than the GCS mild and moderate groups. The GCS severe group had the highest proportions of children with a temporary loss of consciousness, coma, PICU admission, surgery, all tubes and lines, blood transfusions, and hospital medications in Table 4. A much smaller proportion of children in the GCS severe group were discharged home than the mild and moderate groups. About half of the children in the GCS severe group were discharged with a new chronic condition; however, the proportions of children discharged with medications and/or equipment were similar across GCS groups. By discharge, 35 of the 38 children in the moderate and severe GCS groups had improved GCS scores: 13 children in the moderate group and 18 in the severe group improved to the GCS “mild” group, and four children in the GCS severe group improved to the GCS “moderate” group.

Discussion

Consistent with national data (Faul et al., 2010), the most common injury event for the preschoolers in this study was falls followed by being hit by a car or being a passenger in a motor vehicle crash. More than half (63%) received treatment at the scene, with 90% from emergency medical services, perhaps reflecting the primarily urban catchment areas of the seven hospitals. The majority of head-injured children were admitted through the emergency room or directly to one of the seven tertiary care hospitals. Most of the children transferred to the tertiary care hospital from another hospital were admitted in good, fair, or stable condition (85%) to the GCU (59%) and had sustained a head injury with no other injuries (72%) during a fall (48%). Given this description, perhaps the child’s young age, in conjunction with type of injury and level of pediatric care available at the other hospital, precipitated the transfer to the tertiary care facility rather than the child’s condition.

The classification of preschoolers’ head injury severity differed between the head AIS categories and the GCS categories, with only 50 children in the same AIS and GCS categories – 23 mild, 6 moderate, and 21 severe in both classification schemes. The GCS underestimated anatomical head injury severity for 122 (69%) children and overestimated it for four (23%) children. A much higher proportion of children in the GCS mild category were admitted to the PICU than those with AIS mild head injuries. The head AIS score produced more distinct and homogeneous head injury severity groups regarding numbers and types of procedures than the GCS categories. Children who required more aggressive treatment and PICU admission were also more clearly identified by the serious and severe head AIS category than the severe GCS category. Discharge disposition was significantly related to AIS head injury category, the lowest GCS category, and the discharge GCS category. Despite the number of moderate to severe head injuries, only 11 preschool children were discharged to another treatment facility (one to another hospital, five to a rehabilitation facility, and five to a long-term care facility). All had been admitted initially to the PICU, and nine were categorized in the severe group by both the lowest GCS in the first 24 hours and the head AIS classification. The other two were in the serious AIS category and the moderate GCS category. These 11 children were evenly distributed across the three GCS categories at discharge.

Perhaps these differences reflect the goal of each injury severity scoring system. The GCS was developed to facilitate the assessment of the initial brain injury after severe trauma (Teasdale & Jennett, 1974). Clinicians use the GCS to communicate child condition within and across settings –the scene of the injury event, the emergency department, the PICU, and the GCU – because it is simple to use, requires no scans to score, and provides information about changes in a child's neurologic status. Demetriades et al. (2004) and Foreman et al. (2007) found the GCS to be an effective predictor of outcomes in children with TBI. The most valid time to assess GCS for prognosis may be after resuscitation and stabilization; however, many children are intubated and pharmaceutically paralyzed and/or sedated at that time, making a full and valid GCS assessment impossible (Grinkeviciute et al., 2007).

In contrast, the AIS was developed to characterize the amount and type of anatomical injury in each of six body regions. Radiologic procedures are required for scoring injury severity in many of the AIS body regions, including the head. Kilgo, Osler, and Meredith (2003) found that the child's worst injury discriminates survival outcome, regardless of the type of scoring system used. If so, the head AIS may be more helpful in directing care and predicting disposition at discharge because it is based strictly on the characteristics of the injury and does not use any physiologic variables or change over time. This specific feature of the AIS makes it controversial in predicting the outcome of TBI for some (Signorini, Andrews, & Jones, 1999). While a GCS score was not possible for five children in the first 24 hours and was not recorded for 11 children at discharge, AIS head injury severity could be scored for all but three children in this study.

Several factors are known to influence outcomes after TBI, including age, injury event, level of severity, associated injuries, and concomitant hypoxia or intracranial complications. Hypoxia and secondary intracranial complications can be reduced with aggressive interventions, but these treatments can increase medical complications. Earlier interventions, such as intubation at the injury scene, may also improve outcomes (Adelson et al., 2003). In this study, age and gender of the injured child and receipt of treatment at the injury site did not differ by admission unit, types of injuries, or head AIS and GCS severity categories. The restricted child age range and the high proportion of treatment at the scene by health care providers may have limited the impact of these variables. Children admitted to the PICU, those with TBI and organ damage, those with AIS serious and severe/critical head injuries, and children with GCS severe head injuries received more brain-sparing treatments and medications. All 13 of the children in the GCS moderate group and four of the 25 children in the GCS severe group improved in neurologic functioning between the first 24 hours and hospital discharge.

The outcome of severe TBI is not disputed. However, there is growing evidence that younger children are more adversely affected by head injury. Long-lasting impairments may appear as the child develops. In three- to seven-year-old children who sustained severe brain injuries, Anderson, Catroppa, Morse, and Rosenfeld (2003) found minimal recovery in IQ by 12 months post-injury. Yeates et al. (2004) found that cognitive sequelae had not resolved four years post-injury in six-to 12-year-old children with moderate to severe brain injury. Halldorsson et al. (2008) suggested that children with minimal/mild brain injuries may demonstrate late sequelae as well. Misdiagnosis may lead to less than optimal interventions and outcome. Slomine et al. (2006) reported that a substantial proportion of children with TBI had unmet or unrecognized cognitive health care needs during the first year post-injury. Based on their study's findings, Swaine et al. (2007) concluded that children who do not regain their pre-injury health status could be at risk for subsequent injuries. Even subtle deficits in coordination, balance, or endurance, combined with cognitive and behavioral limitations, may increase the child's risk for subsequent injury. The physical and/or neurologic consequences of a preschooler's head injury can affect the child's functioning at school and home, as well as functioning of the family unit (Keenan, Runyan, & Nocera, 2007; Youngblut & Brooten, 2008).

Implications for Clinical Practice and Future Research

Head injury is a common occurrence for preschool children that can have long-term sequelae. Rapid assessment and treatment can limit the devastating effects of TBI. In this study, the head AIS categories clustered children in more homogeneous groups and better represented the hospital care children received than the GCS in the first 24 hours. Although considered the gold standard for identifying and communicating clinical changes in cognitive and/or neurologic status, the GCS may be less helpful in representing or guiding hospital care. In contrast to scoring all six AIS body regions, scoring only the head injury with the AIS is quick enough for clinical use and may be an important addition to the GCS. The head AIS was a better indicator of both injury severity and care provided than the GCS. However, failure to attain a "normal" GCS by hospital discharge may better predict long-term deficits in cognitive and/or brain functioning. Research is needed to investigate the ability of the head AIS, alone and in conjunction with the GCS, to identify long-term effects of TBI for preschool children and their families.

Acknowledgments

This research was supported by a grant from the National Institutes of Health, National Institute of Nursing Research, R01-NR04430.

References

Adelson P, Bratton S, Carney N, Chestnut R, du Coudray H, Goldstein B, Wright D. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. Pediatric Critical Care Medicine. 2003; 4(3):1–75.

American Academy of Pediatrics (AAP). The management of minor closed head injury in children. Committee on quality improvement, American Academy of Pediatrics. Commission on clinical policies and research, American Academy of Family Physicians. Pediatrics. 1999; 104(6):1407–1415. [PubMed: 10585999]

Anderson V, Catroppa C, Morse S, Rosenfeld J. Recovery of intellectual ability following traumatic injury in children. Pediatric Neurosurgery. 2003; 32:282–290. [PubMed: 10971189]

Association for Advancement of Automotive Medicine (AAAM). Abbreviated injury scale. Des Plaines, IL: Author; 1990.

Bowman S, Bird T, Aitken M, Tilford J. Trends in hospitalizations associated with pediatric traumatic brain injuries. Pediatrics. 2008; 122(5):988–993. [PubMed: 18977977]

Demetriades D, Kuncir E, Murray J, Velmahos G, Rhee P, Chan L. Mortality prediction of head abbreviated injury score and Glasgow coma scale: Analysis of 7,764 head injuries. Journal of American College of Surgeons. 2004; 199(2):216–222.

Dunning J, Daly J, Lomas F, Batchelor J, Mackway-Jones K. Deviation of children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. Archives of Diseases in Childhood. 2006; 91:885–891. [PubMed: 17056862]

Faul, M.; Wald, M.; Coronado, V. Brain injury in the United States: Emergency department visits, hospitalizations, and deaths 2002–2006. Atlanta: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010.

Foreman B, Caesar R, Parks J, Madden C, Gentilello L, Shafi S, Diaz-Arrastia R. Usefulness of the abbreviated injury score and the injury severity score in comparison to the Glasgow coma scale in predicting outcome after traumatic brain injury. Journal of Trauma, Injury, Infection, and Critical Care. 2007; 62(4):946–950.

Goldberg J, McClaine R, Cook B, Garcia V, Brown B, Crone K, Falcone R. Use of a mild traumatic brain injury guideline to reduce inpatient hospital imagining and charges. Journal of Pediatric Surgery. 2011; 46(9):1777–1783. [PubMed: 21929989]

Grinkeviciute D, Kevalas R, Saferis V, Matukevicius A, Ragaisis V, Tamasauskas A. Predictive value of scoring system in severe pediatric head injury. Medicina (Kaunas). 2007; 43:861–869. [PubMed: 18084143]

Halldorsson J, Flekkoy K, Arnkelsson G, Tomasson K, Gudmundsson K, Arnarson E. The prognostic value of injury severity, location of event, and age at injury in pediatric traumatic head injuries. Neuropsychiatric Disease and Treatment. 2008; 4:405–412. [PubMed: 18728737]

Keenan H, Runyan D, Nocera M. Longitudinal follow-up of families and young children with head injury. Pediatrics. 2007; 117:1291–1297. [PubMed: 16585326]

Kilgo P, Osler T, Meredith W. The worst injury predicts mortality outcome the best: Rethinking the role of multiple injuries in trauma outcome scoring. Journal of Trauma. 2003; 56:599–607. [PubMed: 14566109]

Signorini D, Andrews P, Jones P. Predicting survival using simple clinical variables: A case study in traumatic brain injury. Journal of Neurology Neurosurgery Psychiatry. 1999; 66:20–25.

Slomine B, McCarthy M, Ding R, MacKenzie E, Jaffe K, Aitken M. CHAT Study Group. Health care utilization and needs after pediatric traumatic brain injury. Pediatric. 2006; 117:e663–e674.

Swaine B, Tremblay C, Platt R, Grimard G, Zhang X, Pless I. Previous head injury is a risk factor for subsequent head injury in children: A longitudinal cohort study. Pediatrics. 2007; 119:749–758. [PubMed: 17403846]

Teasdale G, Jennett B. Assessment of coma and impaired consciousness: A practical scale. Lancet. 1974; 2:81–84. [PubMed: 4136544]

Walker P, Harting M, Baumgartner J, Fletcher S, Strobel N, Cox C. Modern approaches to pediatric brain injury therapy. Journal of Trauma. 2009; 67(2):S120–S127. [PubMed: 19667844]

Yeates K, Swift E, Taylor H, Wade S, Drotar D, Stancin T, Minich N. Short- and long-term social outcomes following pediatric brain injury. Journal of International Neuropsychiatry. 2004; 10:412–426.

Youngblut J, Brooten D. Pediatric head trauma: parent-child and family functioning 2 weeks after hospital discharge. Journal of Pediatric Psychology. 2006; 31:608–618. [PubMed: 16120765]

Youngblut J, Brooten D. Mother's mental health, mother-child relationship, and family functioning 3 months after a preschooler's head injury. Journal of Trauma Rehabilitation. 2008; 23:92–102.

Youngblut J, Brooten D, Kuluz J. Parent reactions at 24–48 hours after a preschool child's head injury. Pediatric Critical Care Medicine. 2005; 6:550–556. [PubMed: 16148816]

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Child Description and Treatment by Type of Injury

	TBI Only (*n* = 123)	TBI + Fracture (*n* = 37)	TBI + Organ Damage (*n* = 9)	TBI + Fracture + Organ Damage (*n* = 12)	Statistic
Child Description					
Boys (*n* [%])	70 (56.9)	24 (64.9)	4 (44.40)	4 (33.3)	$\chi^2 = 4.2$
Child age in months (M [SD])	59.4 (14.42)	60.1 (16.01)	63.1 (18.14)	63.2 (12.94)	F = 0.4
Length of stay in days (M [SD])[1]	1.8 (1.39)[ab]	3.5 (3.21)[a]	8 (7.76)	13.6 (11.74)[b]	F = 38.9**
Total injury severity (M [SD])[1]	9.0 (8.30)[ab]	15.5 (11.50)[a]	21.1 (16.95)	24.8 (12.56)[b]	F = 14.5**
Head AIS (M [SD])	7.8 (8.71)	10.8 (13.33)	10.6 (8.06)	10.9 (7.80)	F = 1.2
Lowest GCS (M [SD])[1]	13.6 (2.71)[a]	13.2 (3.46)[b]	9.7 (5.50)[ab]	9.4 (5.28)[ab]	F = 9.1**
Temporary loss of consciousness (*n* [%])	47 (38.2)	13 (35.1)	2 (22.20)	11 (91.7)	$\chi^2 = 13.7$**
Coma (*n* (%)]	2 (1.6)	2 (5.4)	1 (11.10)	4 (33.3)	$\chi^2 = 23.9$**
Treatments [*n* [%])					
PICU admission	50 (40.7)	22 (59.5)	7 (77.80)	10 (83.3)	$\chi^2 = 13.7$**
Treated at scene	72 (58.5)	21 (56.8)	8 (88.90)	10 (83.3)	$\chi^2 = 7.4$
Surgery	17 (13.8)	23 (62.2)	2 (25.00)	8 (66.7)	$\chi^2 = 42.8$**
Urinary catheter	29 (23.6)	15 (40.5)	7 (77.80)	10 (83.3)	$\chi^2 = 26.8$**
Gastric tube	17 (13.8)	9 (24.3)	7 (77.80)	10 (83.3)	$\chi^2 = 44.4$**
Endotracheal tube	17 (13.8)	16 (43.2)	6 (66.70)	7 (58.3)	$\chi^2 = 29.9$**
Chest tube	0	0	1 (11.10)	3 (25.0)	$\chi^2 = 35.5$**
Arterial line	3 (2.4)	5 (13.5)	5 (55.60)	7 (58.3)	$\chi^2 = 54.6$**
CVP line	0	1 (2.7)	3 (33.30)	4 (33.3)	$\chi^2 = 47.2$**
ICP line	1 (0.8)	1 (2.7)	2 (22.20)	3 (25.0)	$\chi^2 = 25.5$**
Wound drains	1 (0.8)	3 (8.1)	0	2 (16.7)	$\chi^2 = 11.9$**
Blood products	0	4 (10.8)	2 (22.20)	5 (41.7)	$\chi^2 = 39.9$**
Medications (*n* [%])					
Phenytoin	10 (8.1)	6 (16.2)	3 (33.3)	4 (33.3)	$\chi^2 = 11.4$**

	TBI Only (n = 123)	TBI + Fracture (n = 37)	TBI + Organ Damage (n = 9)	TBI + Fracture + Organ Damage (n = 12)	Statistic
Phenobarbital	0	4 (10.8)	1 (11.1)	2 (16.7)	$\chi^2 = 16.7^{**}$
Pentobarbital coma	4 (3.3)	2 (5.4)	3 (33.3)	2 (16.7)	$\chi^2 = 15.9^{**}$
Mannitol/Urea	4 (3.3)	2 (5.4)	3 (33.3)	3 (25.0)	$\chi^2 = 19.9^{**}$
Pancuronium bromide	1 (0.8)	1 (2.7)	1 (11.1)	0	$\chi^2 = 5.8$
At Discharge (*n* [%])					
Discharged home	121 (98.3)	36 (97.3)	6 (66.7)	7 (58.3)	$\chi^2 = 43.4^{**}$
Discharged with chronic condition	20 (16.3)	6 (16.2)	4 (57.1)	7 (58.3)	$\chi^2 = 16.6^{**}$
Discharged with medications	6 (54.5)	32 (86.5)	4 (57.1)	9 (75.0)	$\chi^2 = 14.0^{**}$
Discharge with equipment	6 (4.9)	11 (29.7)	1 (16.7)	7 (58.3)	$\chi^2 = 37.7^{**}$

[1] Superscripts of matching letters indicate significantly different means. For example, mean[a] is significantly different from the other means with the same superscript (mean[a]) in that line. However, mean[a] is NOT significantly different from means with other superscripts (mean[b] or mean[c]) in that line.

* $p < 0.05$

** $p < 0.01$

Table 2

Comparison of Lowest GCS Category and Head AIS Score Categories*

Lowest GCS Categories	Head AIS Categories				Total %
	Mild	**Moderate**	**Serious**	**Severe/Critical**	
Mild	**23**	62	26	26	137 (77.8)
Moderate	0	**6**	3	5	14 (8.0)
Severe	1	3	**10**	**11**	25 (14.2)
Total %	24 (13.6)	71 (40.3)	39 (22.2)	42 (23.9)	176 (100)

$\chi^2 = 21.09$, $p = .002$

*Bold cells indicate children in the same severity category on the GCS and AIS

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 3

Child Description and Treatment by Head AIS Categories

	Mild Only (*n* = 25)	Moderate (*n* = 71)	Serious (*n* = 40)	Severe/Critical (*n* = 44)	Statistic
Child Description					
Boys (*n* [%])	18 (72.0)	36 (50.7)	22 (55.0)	25 (56.8)	$\chi^2 = 3.2$
Child age in months (M [SD])	56.5 (13.69)	59.8 (13.45)	61.9 (15.27)	604 (16.71)	F = .71
Length of stay in days (M [SD])[1]	2.3 (4.21)	1.6 (0.97)[ab]	3.8 (4.17)[a]	6.0 (7.76)[b]	F = 8.8**
Total injury severity (M [SD])[1]	3.1 (3.51)[a]	7.0 (3.88)[a]	12.1 (3.94)[a]	21.8 (9.12)[a]	F = 84.0**
Lowest GCS (M [SD])[1]	14.6 (1.67)[ab]	13.8 (2.23)[c]	11.9 (4.33)[a]	11.7 (4.43)[bc]	F = 6.7**
Temporary loss of consciousness (*n* [%])	6 (24.0)	32 (45.1)	18 (80.0)	16 (36.4)	$\chi^2 = 3.7$
Coma (*n* (%)]	1 (4.0)	0	1 (2.5)	7 (15.9)	$\chi^2 = 15.1$**
Treatments [*n* [%])					
PICU admission	5 (20.0)	21 (29.6)	28 (70.0)	35 (79.5)	$\chi^2 = 42.6$**
Treated at scene	17 (68.0)	46 (64.8)	22 (55.0)	24 (54.5)	$\chi^2 = 2.5$
Surgery	4 (16.0)	18 (25.4)	9 (22.5)	18 (40.9)	$\chi^2 = 6.5$
Urinary catheter	3 (12.0)	16 (22.5)	18 (45.0)	24 (54.5)	$\chi^2 = 22.1$**
Gastric tube	2 (8.0)	11 (15.5)	12 (30.0)	18 (40.9)	$\chi^2 = 14.3$**
Endotracheal tube	1 (4.0)	8 (11.3)	15 (37.5)	22 (50.0)	$\chi^2 = 30.1$**
Chest tube	0	0	1 (2.5)	3 (6.8)	$\chi^2 = 6.6$
Arterial line	0	1 (1.4)	5 (12.5)	14 (31.8)	$\chi^2 = 29.6$**
CVP line	0	0	2 (5.0)	6 (13.6)	$\chi^2 = 13.5$**
ICP line	0	0	2 (5.0)	5 (11.4)	$\chi^2 = 11.0$**
Wound drains	0	0	2 (5.0)	4 (9.1)	$\chi^2 = 8.3$*
Blood products	0	1 (1.4)	2 (5.0)	8 (18.2)	$\chi^2 = 15.9$**
Medications (*n* [%])					
Phenytoin	1 (4.0)	3 (4.2)	8 (20.0)	11 (25.0)	$\chi^2 = 14.3$**
Phenobarbital	0	1 (1.4)	1 (2.5)	5 (11.4)	$\chi^2 = 9.0$*

NIH-PA Author Manuscript
NIH-PA Author Manuscript

	Mild Only (*n* = 25)	**Moderate (*n* = 71)**	**Serious (*n* = 40)**	**Severe/Critical (*n* = 44)**	**Statistic**
Pentobarbital coma	1 (4.0)	1 (1.4)	3 (7.5)	6 (13.6)	$\chi^2 = 7.4$
Mannitol/Urea	1 (4.0)	0	3 (7.5)	8 (18.2)	$\chi^2 = 14.8^{**}$
Pancuronium bromide	0	0	0	3 (6.8)	$\chi^2 = 9.4^{*}$
At Discharge (*n* [%])					
Discharged home	24 (100.0)	71 (100.0)	38 (95.0)	35 (79.5)	$\chi^2 = 21.9^{**}$
Discharged with chronic condition	5 (20.0)	11 (15.5)	7 (17.5)	14 (31.8)	$\chi^2 = 4.7$
Discharged with medications	12 (48.0)	44 (62.0)	27 (67.4)	27 (61.4)	$\chi^2 = 2.6$
Discharge with equipment	3 (12.0)	11 (15.5)	6 (15.0)	5 (11.4)	$\chi^2 = .32$

[1] Superscripts of matching letters indicate significantly different means. For example, mean[a] is significantly different from the other means with the same superscript (mean[a]) in that line. However, mean[a] is NOT significantly different from means with other superscripts (mean[b] or mean[c]) in that line.

* $p < 0.05$

** $p < 0.01$

Table 4

Child Description and Treatment by Lowest GCS Categories

	Mild Only (*n* = 140)	Moderate (*n* = 13)	Severe (*n* = 25)	Statistic
Child Description				
Boys (*n* [%])	78 (55.7)	8 (61.5)	14 (56.0)	$\chi^2 = 0.01$
Child age in months (M [SD])	59.0 (14.7)	64.4 (12.19)	64.3 (15.74)	F = 2.0
Length of stay in days (M [SD])[1]	2.2 (2.42)[a]	3.0 (3.19)[b]	9.7 (9.52)[ab]	F = 33.9**
Total injury severity (M [SD])[1]	10.3 (9.95)[a]	12.0 (7.18)[b]	21.2 (13.6)[ab]	F = 11.8**
Head injury severity (M [SD])[1]	8.0 (10.54)	9.4 (5.50)	12.2 (6.65)	F = 2.0
Temporary loss of consciousness (*n* [%])	43 (30.7)	9 (69.2)	20 (80.0)	$X^2 = 25.6^{**}$
Coma (*n* (%)]	2 (1.4)	0	7 (28.0)	$X^2 = 33.4^{**}$
Treatments [*n* [%])				
PICU admission	54 (38.6)	10 (76.9)	23 (92.0)	$X^2 = 28.7^{**}$
Treated at scene	81 (57.9)	8 (61.5)	22 (88.0)	$X^2 = 7.1^{*}$
Surgery	34 (24.3)	5 (38.5)	11 (44.0)	$X^2 = 5.4$
Urinary catheter	33 (23.6)	6 (46.2)	22 (88.0)	$X^2 = 39.2^{**}$
Gastric tube	20 (14.3)	4 (30.8)	19 (76.0)	$X^2 = 44.1^{**}$
Endotracheal tube	17 (12.1)	4 (30.8)	22 (88.0)	$X^2 = 67.0^{**}$
Chest tube	0	0	4 (16.0)	$X^2 = 24.9^{**}$
Arterial line	5 (3.6)	2 (15.4)	13 (52.0)	$X^2 = 49.8^{**}$
CVP line	0	0	8 (32.0)	$X^2 = 50.9^{**}$
ICP line	0	0	7 (28.0)	$X^2 = 44.0^{**}$
Wound drains	2 (1.4)	1 (7.7)	3 (12.0)	$X^2 = 8.0^{*}$
Blood products	1 (0.7)	0	10 (40.0)	$X^2 = 57.0^{**}$
Medications (*n* [%])				
Phenytoin	9 (6.4)	1 (7.7)	13 (52.0)	$X^2 = 41.0^{**}$
Phenobarbital	1 (0.7)	1 (7.7)	5 (20.0)	$X^2 = 22.0^{**}$
Pentobarbital coma	2 (1.4)	0	9 (36.0)	$X^2 = 46.1^{**}$
Mannitol/Urea	1 (0.7)	0	11 (44.0)	$X^2 = 66.2^{**}$
Pancuronium bromide	1 (0.7)	0	2 (8.0)	$X^2 = 7.3^{*}$
At Discharge (*n* [%])				
Discharged home	140 (100.0)	11 (84.6)	16 (64.0)	$X^2 = 49.5^{**}$
Discharged with chronic condition	23 (16.4)	1 (7.7)	13 (52.0)	$X^2 = 19.1^{**}$
Discharged with medications	85 (60.7)	10 (76.9)	16 (64.0)	$X^2 = 3.3$
Discharge with equipment	19 (13.6)	1 (7.7)	5 (20.0)	$X^2 = 1.9$

[1] Superscripts of matching letters indicate significantly different means. For example, mean[a] is significantly different from the other means with the same superscript (mean[a]) in that line. However, mean[a] is NOT significantly different from means with other superscripts (mean[b] or mean[c]) in that line.

* $p < 0.05$

** $p < 0.01$