HHS Public Access

Author manuscript

Epidemiology. Author manuscript; available in PMC 2019 March 01.

Published in final edited form as:

Epidemiology. 2018 March ; 29(2): 269–279. doi:10.1097/EDE.0000000000000791.

The Epidemiology of Pediatric Head Injury Treated Outside of Hospital Emergency Departments

Cheryl K. Zogg, MSPH, MHS[a,b,c], **R. Sterling Haring, DO, MPH**[b,c,d], **Likang Xu, MD, MS**[e], **Joseph K. Canner, MHS**[c], **Hatim A. AlSulaim, MD, MPH**[c], **Zain G. Hashmi, MD**[b,c], **Ali Salim, MD, FACS**[b,f], **Lilly D. Engineer, DrPH, MD, MHA**[c,g], **Adil H. Haider, MD, MPH, FACS**[b,f], **Jeneita M. Bell, MD, MPH**[e], and **Eric B. Schneider, PhD**[b,c,h]

[a]Yale School of Medicine, New Haven, CT

[b]Center for Surgery and Public Health: Harvard Medical School, Harvard T.H. Chan School of Public Health, and the Department of Surgery, Brigham & Women's Hospital, Boston, MA

[c]Johns Hopkins Surgery Center for Outcomes Research, Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD

[d]Department of Health Policy & Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

[e]National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA

[f]Division of Trauma, Burn, and Surgical Critical Care, Brigham & Women's Hospital, Boston, MA

[g]Department of Anesthesiology & Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

[h]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Abstract

Background—Although head trauma-related deaths, hospitalizations, and emergency department visits are well characterized, few studies describe pediatric patients presenting outside of emergency departments. We compared the epidemiology and extent of healthcare-seeking

Address correspondence to: Cheryl K. Zogg, MSPH, MHS, Yale School of Medicine, 67 Cedar Street, Room 316 ESH, New Haven, CT 06510, Phone: (612) 810-2770, czogg@jhmi.edu.

This work was previously presented as an oral presentation at the American College of Surgeons Clinical Congress Scientific Forum, October 16-20, 2016, in Washington, DC.

Disclosure: The findings and conclusion of this research are those of the authors and do not represent the official views of the US Department of Health and Human Services (DHHS) and the Centers for Disease Control and Prevention (CDC). The inclusion of individuals, programs, or organizations in this article does not constitute endorsement by the US federal government, DHHS, or CDC.

Conflict of interest: Two of the study's co-authors, Likang Xu, MD, MS, and Jeneita M. Bell, MD, MPH, are employees of the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention.

Author contributions: CKZ, RSH, LX, and ESB made substantial contributions to the conception or design of the work, CKZ, RSH, LX, JKC, and ESB participated in the acquisition and analysis of the data, CKZ, RSH, LX, JKC, HAA, ZGH, AL, LDE, AHH, JMB, and EBS contributed toward the interpretation of data for the work, CKZ, RSH, and EBS drafted the manuscript, and LX, JKC, HAA, ZGH, AL, LDE, AHH, and JMB critically revised the manuscript for intellectual content. All authors provided final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

pediatric (0-17y) patients presenting in outpatient settings with those of patients seeking non-hospitalized emergency department care.

Methods—We used MarketScan Medicaid and commercial claims, 2004-2013, to identify patients managed in two outpatient settings (physician's offices/clinics, urgent care) and the emergency department. We then examined differences in demographic and injury-specific factors, CDC-defined head trauma diagnoses, the extent of and reasons for post-index visit ambulatory care use within 30/90/180 days, and annual and monthly variations in head trauma trends. Outpatient incidence rates in 2013 provided estimates of the nationwide US outpatient burden.

Results—A total of 1,683,097 index visits were included, representing a nationwide burden in 2013 of 844,660 outpatient cases, a number that encompassed 51% of healthcare-seeking head trauma that year and that substantially increased in magnitude from 2004-2013. Two-thirds (68%) were managed in outpatient settings. While demographic distributions varied with index-visit location, injury-specific factors were comparable. Seasonal spikes appeared to coincide with school sports.

Conclusions—There is an urgent need to better understand the natural history of head trauma in the >800,000 pediatric patients presenting each year for outpatient care. These outpatient injuries, which are more than double the number of head trauma cases recorded in hospital-affiliated settings, illustrate the potential importance of expanding inclusion criteria in surveillance and prevention efforts designed to address this critical issue.

Keywords

pediatric; head trauma; traumatic brain injury; concussion; ambulatory

Introduction

Head trauma is an important cause of death and disability among pediatric patients aged 0-17y.[1–6] In 2013, head trauma-related injuries were implicated in 2,438 pediatric deaths, 23,980 hospital discharges, and 792,111 non-hospitalized emergency department visits.[6] Much of our understanding of this burden comes from work by the Centers for Disease Control and Prevention (CDC), who in 2004 first illustrated the extent of variability in head trauma treatment as a pyramid with deaths at the pyramid's peak, followed by inpatient hospitalizations, emergency department visits, and a collective group, expected to be the largest in number, who seek other types of care or receive no care (Figure 1).[1–3,6] At the time, the CDC noted that “[t]here is no estimate for the number of people with non-fatal [head trauma] seen outside of an emergency department or hospital setting.”[2,3] More than a decade later (Figure 1), a robust understanding of deaths, hospitalizations, and emergency department presentations for pediatric patients has been developed; however, national estimates of head trauma and treatment outside of the emergency department remain largely unreported. Previous studies that have sought to estimate the volume of pediatric patients consulting non-emergency department providers (*e.g.* community-based physician's offices or urgent care clinics) have been small in scope, frequently relied on locally collected data, and demonstrated substantial variability in the criteria used to define the study population, thus limiting the possibility of extrapolation to the national level.[7–14]

Recognizing the importance of this issue, providers and policymakers have begun to call for enhanced surveillance and a more nuanced understanding of the epidemiology of minor head injury and concussion.[15,16] To plan for the proper prevention, acute care, rehabilitation, and disability support services required to maximize the quality of life for pediatric patients with head trauma, the extent of the problem needs to be better understood.[3,15] The challenge is that, consistent with the CDC's pyramid, surveillance has also primarily focused on deaths, inpatients, and emergency department patients,[4,5,17] limiting our ability to account for healthcare-seeking patients within the lowest pyramid-tier. Estimates that exclude such patients "cannot be assumed to reflect the entire population of persons with [head trauma]" because they have no way to account for the portion of the population who are never treated within the hospital system.[17]

In order to address these concerns and begin characterizing the national burden of head trauma treated in non-hospital outpatient settings, the objectives of this study were to:

1. Estimate the national burden of pediatric head trauma in patients seeking care as outpatients
2. Define epidemiologic characteristics of the population, including demographic and injury-specific factors, CDC-defined head trauma diagnoses, and the extent of and reasons for post-index visit ambulatory care use within 30/90/180 days
3. Examine temporal and seasonal variability in outpatient presentation.

Methods

Study population

We abstracted ten years of data, 2004-2013, from the Truven Health Analytics MarketScan Research Databases: Medicaid and Commercial Claims and Encounters.[18,19] MarketScan provides longitudinal information on adjudicated and paid insurance-claims filed for the care of individuals with employment-based private insurance and coverage provided by the Centers for Medicare & Medicaid Services. It represents the largest national record of pediatric outpatient data.

eFigure 1 details inclusion/exclusion criteria. We included index outpatient visits—defined as initial office/clinic or urgent care presentations with subsequent care received exclusively in ambulatory settings—with ICD-9-CM diagnosis codes consistent with the CDC's traumatic brain injury definition.[1–3,6] For the purposes of this analysis, we defined ambulatory visits to include presentations to both outpatient and emergency department settings. Index emergency department visits meeting the same criteria were included as a reference. We excluded visits treated in other locations or that contained information for follow-up visits after the provision of inpatient care as well as any visits corresponding to referrals to higher levels of care, such as subsequent inpatient admissions. The first point of contact in an outpatient or emergency department setting was defined as the location for the index visit. For patients with multiple visits, 180 days were required to have passed since a previous index visit in order to constitute a second index visit with no indication of follow-up care in the 30 days prior to the second visit. The work also excluded visits for patients

aged >17y and for patients missing information, unless otherwise specified by missing indicator variables.

We categorized included index visits into three groups: urgent care, office/clinic, and emergency department. We compared demographic and injury-specific patient-level characteristics for office/clinic and urgent care visits relative to non-hospitalized emergency department visits. Demographic factors included age, sex, insurance, region, and year. Injury-specific characteristics included loss of consciousness derived from ICD-9-CM codes, Charlson Comorbidity Index, Pediatric Surgical Risk Score,[20] maximum-head Abbreviated Injury Scale, and overall Injury Severity Score. Comorbidity indexes and injury severity scores were calculated using ICD-9-CM diagnosis and E-codes. Analogous assessment was conducted for CDC-defined head trauma diagnoses and for differences in post-index visit ambulatory care use.

Temporal and seasonal trends

We examined temporal trends by year, stratified by index-visit location and type of insurance, using joinpoint-regression.[21–23] Joinpoint-regression is a segmented linear-modeling technique that describes changing trends over successive segments of time and the amount of increase/decrease associated with each.[22–24] Segment connections, termed 'joinpoints', are assigned by the model at places where changes in trend in excess of a predetermined frequentist threshold occur (two-sided *beta* = 0.20, *alpha* = 0.05). Slopes join linear segments between them and provide estimates of the annual percent change during that period. An overall average annual percent change is calculated as the weighted geometric average of the segment slopes with weights set equal to the segment lengths.[22–24] Two joinpoints were allowed. Seasonal trends in the rate of health care-seeking outpatient head trauma per 100,000 pediatric enrollees were also examined by month from January 2010-December 2013. Variations were assessed overall and stratified by insurance.

National estimates of the outpatient burden

National estimates in 2013 were obtained by taking observed rates of (insurance-specific) office/clinic, urgent care, and emergency department visits per 100,000 pediatric enrollees and multiplying by the size of the (insurance-specific) segment of the 2013 US pediatric population.[25] Uninsured use was assumed equal to the national Medicaid rate. Sensitivity analyses assessed alternative specifications in which the uninsured rate was set equal to 10%, 25%, 50%, or 150% of the Medicaid rate. None appreciably changed estimated burden size (eTable 1). A second set of sensitivity analyses addressed the possibility of misclassification, adjusting 2013 population estimates to account for 5%, 10%, or 20% over- or underestimation (eTable 2). Comparison of MarketScan data to CDC Healthcare Cost and Utilization Project-based surveillance data for pyramid treatment tiers two and three is presented in eTable 3. Extrapolation of uncertainty reported in US Census Bureau[25] data provided 90% confidence intervals (CI).

The study calculated provider time for index visits based on the average length of time (~7 minutes) anticipated for a routine office or emergency department visit. Information for this calculation was derived from ambulatory care data from the CDC's National Center for

Health Statistics and previously published research on time allocation in primary care.[26,27] Statistical analyses were conducted using Stata Statistical Software: Release 14.1 and SAS/STAT: Release 9.4. The CDC and Johns Hopkins Institutional Review Board approved the study.

Results

National burden of outpatient pediatric head trauma

A combined total of 1,683,097 index ambulatory pediatric visits were included. Approximately one-third (32%) were treated in a hospital emergency department, 66% in a physician's office/clinic, and 2% in a dedicated urgent care center. Outpatient visits consistent with the lowest pyramid-tier—office/clinic, urgent care—represented more than two-thirds of visits for ambulatory care. Nationwide in 2013, they corresponded to an estimated annual incidence of 844,660 outpatient visits (90%CI: 830, 797-858, 524) and 98,544 hours of provider time (Table 1). When emergency department visits were included, the numbers increased to 1.26 million annual index visits (90%CI: 1.24-1.28 million) and 146,704 hours of provider time.

Epidemiologic characteristics

Tables 2-3 and Figure 2 detail distributions of epidemiologic characteristics stratified by index-visit location, including variations in demographic and injury-specific factors, CDC-defined head trauma diagnoses, and post-index visit ambulatory care use.

Demographic patient factors—In the emergency department, the proportion of ambulatory visits decreased as pediatric patients aged, dropping from 33% among children aged 0-2y to 14% among adolescents aged 15-17y (Table 2). Children 0-2y comprised the highest proportion of visits to urgent care (26%) and 21% of office/clinic visits. The proportion of urgent care visits also decreased with age, while the proportion of office/clinic visits increased (3-5y 14% versus 15-17y 24%). In all three locations, males presented with head trauma more commonly than females (61-62% versus 38-39%, respectively). Differences in insurance were the least pronounced within the emergency department, where Medicaid insured 51% of ambulatory patients. Insurance differences were more pronounced within urgent care (26% Medicaid versus 74%private) and office/clinic settings (19% Medicaid versus 81% private). In 2013, 38% of children in the US aged 0-17y had Medicaid or another form of government-based health insurance plan (*e.g.* TRICARE from a parent working for the Department of Defense); 56% were privately-insured[25]—a distribution which suggests an apparent overrepresentation of Medicaid among ambulatory emergency department visits and under representation among visits to outpatient settings.

Injury-specific patient factors—The majority of visits were consistent with isolated (Injury Severity Score of 4-8:emergency department 96%, urgent care 97%, office/clinic 93%), non-severe head injuries (maximum-head Abbreviated Injury Scale <3: 99%, 99%, 97%); 1% (urgent care) to 4% (office/clinic) were diagnosed with ICD-9-CM codes suggestive of loss of consciousness (Table 2). Most did not present with any pre-existing comorbidity (Charlson Comorbidity Index of 0: 98-99%).

CDC-defined diagnoses—The majority of patients, regardless of location, presented with a diagnosis of “unspecified head injury” (959.01: emergency department 86%, urgent care 80%, office/clinic 71%; Table 3). In the emergency department, >60% were not diagnosed with other coded head trauma diagnoses—a number that decreased to 30% among office/clinic visits. One in four patients were diagnosed with a concussion (850.×: emergency department 17%, office/clinic 31%), and 7% were diagnosed with “other or unspecified” intracranial injuries (854.×: emergency department 6%, office/clinic 8%).

Post-index visit ambulatory care use—Ambulatory patients initially managed in office/clinic settings, on average, presented for 8.9 subsequent ambulatory visits within 180 days (2.3 visits within 30 days) (Figure 2A), resulting in >8 million annual ambulatory visits nationwide (Figure 2B). Emergency department index visits presented for an average of 10.7 post-index visits within 180 days (2.5 visits within 30 days), resulting in approximately 5 million annual ambulatory visits nationwide. These numbers present a striking contrast to the overall population-wide average of 1.2 ambulatory visits reported every 180 days for children and adolescents aged 0-17y in 2012 in the US (an average of 0.2 visits in 30 days).[27]

The 20 most prevalent primary diagnoses recorded on subsequent ambulatory presentation within 30 and 180 days are presented in Table 3. While many corresponded to routine forms of pediatric outpatient care (*e.g.* routine child health exams, influenza vaccinations, acne, and infections), 13 of the 20 most frequent diagnoses within 30 days of head trauma presentation were consistent with head trauma recovery (*e.g.* contusions and open wounds of the head) and associated sequelae (*e.g.* headaches, post-concussion syndrome, and documented changes in consciousness, attention, and activity). Within 180 days, the relative frequency of contusions and open wounds declined as outpatient presentations for childhood infections became more common. Longer-lasting sequelae consistent with head trauma, however, remained among the most frequent diagnoses reported.

Temporal and seasonal trends

The overall annual rate of presentation for outpatient treatment of head trauma increased by more than 50%across the study period, growing from 1,021.3 per 100,000 pediatric enrollees in 2004 to 1,575.0 in 2013 (eTable 4), average annual percent change+7% (95%CI: +5-9%). Annual rates of emergency department visits did not change (2004: 439.8 versus 2013: 455.9; average annual percentage change +1% [95%CI: -2 to +4%]); however, rates of office/clinic (average annual percentage change+9% [95%CI: +7-12%]) and urgent care (+32% [95%CI: 27-37%]) visits both substantially increased. Urgent care use rose from a baseline of 4.5 visits per 100,000 pediatric enrollees in 2004 to 25.7 per 100,000 in 2009 (annual percent change+39%). From 2010-2013, growth slowed slightly, reaching 47.8 visits per 100,000 in 2013 (annual percent change +23%). Office/Clinic visits climbed from 577.0 per 100,000 in 2004 to 1,071.3 per 100,000 in 2013. Changes were primarily driven by an annual percent change of +11% from 2006-2013.In the emergency department, use increased from 439.8 per 100,000 in 2004 to 456.5 in 100,000 in 2009; however, it remained unchanged from 2010-2013.

Temporal trends stratified by insurance and visit location are presented in Figure 3. Patients with private insurance (Figure 3A) and Medicaid (Figure 3B) both exhibited overall increases (average annual percentage change private: +8% [95%CI: 6-10%]; Medicaid: +5% [95%CI: 3-7%]). However, while annual rates of office/clinic visits increased among privately-insured patients (average annual percentage change+9% [95%CI: 7-11%]), corresponding changes among Medicaid patients did not reach threshold (average annual percentage change +5% [95%CI: -1 to +12%]). Office/Clinic visit rates for both groups in 2004 were similar, private: 614.1 versus Medicaid: 528.3 per 100,000.

Seasonal trends in the monthly rate of outpatient head trauma visits are presented in Figure 3C (values eTable 5). Privately insured and Medicaid patients had similar trends, with annual incidence peaks during March-April and, more pronounced, during September-October; decreases during June-August; and a more moderate peak during January each year. The size of seasonal fluctuations among Medicaid patients appeared to remain largely unchanged (*e.g.* October 2010: 182.8 versus 2013: 198.4, a relative +9% increase), while September-October peaks among privately insured patients more substantially increased (October 2010: 184.3 versus 2013: 233.1, a relative +27% increase).

Discussion

This study of the epidemiology and burden of pediatric outpatient head trauma used national data to demonstrate that more than one-half (51%) of all known healthcare-seeking visits for head trauma among pediatric patients occur in non-hospital outpatient settings, primarily in physician's offices and clinics. The observed sample of 1,188,096 privately insured and 495,001 Medicaid index outpatient visits is, to our knowledge, the largest pediatric population examined to date and one of the first to consider the burden of pediatric head trauma presenting for care outside of a hospital emergency department setting. Annual rates among privately insured and Medicaid outpatients suggest that when applied to the national US pediatric population in 2013 (inclusive of uninsured patients),[25] previously unaccounted for treatment of head trauma in office/clinic and urgent care settings would have encompassed as many as 844,660 initial physician visits and 98,544 hours of provider time.

Little is known about the burden of outpatient pediatric head trauma on a national scale. Work by Taylor *et al.*[7] conducted among 10,942 privately insured ambulatory patients in Massachusetts, aged 6-21y, found that from 2007-2013 the proportion of children and adolescents diagnosed with concussion and/or minor head injury increased from 1% to 3%. Outpatient visits for head trauma increased from 16.9 to 67.0 per 1,000 patient-years, with the greatest increases seen in specialist (+919%) and primary-care provider settings(+485%). Emergency department visits increased by a relative +42%.[7] Macpherson *et al.*[14] demonstrated a similar increase in emergency department and office visits for concussion among children and adolescents in Ontario, aged 3-18y, climbing from 340.5 visits per 100,000 pediatric population in 2003 to 601.3 in 2010. In a five-year assessment of data from NAMCS/NHAMCS, 2005-2009, Mannix and colleagues[8] further identified a total of 111 pediatric outpatient office and clinic visits for minor head injury, representing a weighted estimate of 2,045,900 outpatient visits nationwide (an average of 409,200 visits per year).[8] At The Children's Hospital of Philadelphia, 2010-2014, 8,083 patients with

concussion were categorized according to their initial place of presentation; 82% presented to primary care, 5% specialty care, and 12% to the emergency department.[13] Consistent with our findings, they noted that insurance influenced patients' index-visit location with Medicaid patients being the most likely to present to the emergency department, while privately-insured patients were the most likely to present to primary care.[13] Finally, among privately insured patients in MarketScan in 2013, Bryan *et al.*[12] identified 377,978 office/clinic visits for patients diagnosed with concussion without prior healthcare utilization for concussion in the preceding 30 days. Their estimates[12] suggest that there could also be >500,000 additional children and adolescents with sports- and recreation-related concussions not treated in a healthcare setting based on extrapolated projections from injuries for nine high-school sports[28] and published research[29–31] which suggests that 23-53% of such injuries do not receive formal medical care. Our results build on this work,[7–13] providing a more nuanced estimate among observed Medicaid and privately insured index outpatient visits of both the size of the pediatric burden and how it has varied—temporally and seasonally—on a national scale.

Akin to work by Taylor *et al.*[7] and Macpherson *et al.*[14], assessment of temporal trends demonstrated increases in outpatient presentation (overall relative change, 2004-2013: +54%) that were primarily driven by increasing rates of office/clinic visits (+86%) among privately insured patients (+96%). Seasonal variation revealed changes in outpatient presentations throughout the calendar year. Annual peaks during March to April and September to October correspond to the timing of participation in school sports. Drops from June to August coincide with the time when children and adolescents are out of school. Further research is needed to determine how these injuries were sustained. Comparison with known seasonal trends in sports- and recreation-related injuries within the emergency department demonstrate a high degree of similarity to patterns reported for adolescents playing school sports,[32,33] particularly among male patients in the fall, which work by Coronado *et al.*[32] suggests is largely a result of football. Increased awareness of the need for sports/recreational safety;[34–36] introduction of “return to play” laws in all 50 states, which require medical clearance for concussion;[37–39] as well as increased pressure to promote enhanced reporting of concussion and mild head injury, which have historically been underdiagnosed,[40–42] could be driving the increases in outpatient utilization observed. High presentation prevalence among children aged 0-2y in all three index ambulatory locations is in keeping with expectations based on existing emergency department data.[40–42] It likely reflects a tendency for young children to encounter misadventures while learning to walk and crawl at home combined with a heightened awareness of potential head injury among parents of children of younger age.

Increasing outpatient utilization for head injury parallels increasing trends in pediatric emergency department utilization for head injury (subsequent inpatient admissions plus ambulatory-only visits) reported in a recent eight-year weighted assessment of data from the National Emergency Department Sample, 2006-2013.[43] In the study, increasing trends for head injury and for specifically-diagnosed concussion were contrasted by declining rates of ‘severe traumatic brain injury’ (defined as an ICD-9-CM/E-code-derived Abbreviated Injury Scale≥3).[43] Similar declines among inpatient admissions and fatalities have also been reported as have other instances of increasing pediatric emergency department trends.[6]

Taken together, these findings suggest a potentially high level of effectiveness of ongoing head injury prevention work— including increased awareness, policy changes, improved treatment and access to care, equipment and rule modifications in sports, etc.—that are shifting the distribution of head injury among pediatric patients toward less severe clinical indications and less centralized avenues of care. In the coming years, enhanced surveillance capable of addressing these issues and identifying these patients will be essential to continuing to improve the quality of life of pediatric patients with head injury and to appropriately direct resources and attention toward where the problem persists.

Most patients were diagnosed with minor head injuries, 76% with unspecified head injury and 26% with concussion. Thirty percent of index office/clinic visits did not have a second diagnosis recorded during initial presentation other than 959.01, “head injury unspecified.” The interpretation of this code has been a source of controversy, with research suggesting that inclusion/exclusion could result in either over- or underestimation.[43–47] In some studies, it has been assumed to represent mild head injury and/or concussion.[44] Signs and symptoms of concussion are often non-specific. None are pathognomonic, with thresholds for diagnosis tending to vary among clinicians. As a result, it is possible that in a study of index outpatient visits, part of the prevalence of this code could be due to providers' decision to reserve a definitive diagnosis while considering others in the differential, particularly if patients require follow-up care. Further studies are needed to determine the clinical picture and trajectory of this group of outpatients, including an understanding of how they present in clinical settings, their clinical course, and whether they eventually receive a concussion diagnosis.

The study has limitations, several of which come from its reliance on a retrospective administrative database where completeness of information, lack of clinical detail, and accuracy of reporting can be concerns. The study allowed for one of the first assessments of pediatric head trauma treated in an outpatient setting using a large national sample of Medicaid and privately-insured cases. It did not, however, allow for direct assessment of uninsured patients who, while not expected to represent a large proportion of outpatient office/clinic or urgent care use, did constitute 7% of the national pediatric population in 2013.[25] Initial assessment of subsequent ambulatory care use included all patient presentations. Further research is warranted to understand how head trauma-specific trajectories of patients within this population progress over time, relative to other patients and beyond 180 days.

In conclusion, our findings suggest that >800,000 healthcare-seeking pediatric patients with head trauma obtain treatment in non-hospital and non-emergency department settings each year, with most care occurring in physician's offices/clinics. The data demonstrate substantial variations in both temporal and seasonal trends. As efforts to plan for and provide enhanced services to head trauma patients continue to increase, it will be essential to recognize that more than one-half of all pediatric patients with head injury present for initial care outside of a hospital emergency department. Further research is needed to better understand the clinical course and long-term outcomes for pediatric patients with head trauma who are treated exclusively outside of the hospital system. The results illustrate the importance of expanding inclusion criteria in surveillance and prevention efforts designed to

inform head trauma treatment, awareness, prevention, and care for children and adolescents at all levels of the head trauma pyramid.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors would like to thank Fizan Abdullah, MD, PhD, Daniel Rhee, MD, MPH, and Jose H. Salazar Osuna, MD, from the Department of Surgery at Johns Hopkins University School of Medicine and the Division of Pediatric Surgery at Ann & Robert H. Lurie Children's Hospital of Chicago for allowing us to use the analytical files for their Pediatric Surgical Risk Score.

Funding source: No funding specifically for this work was provided.

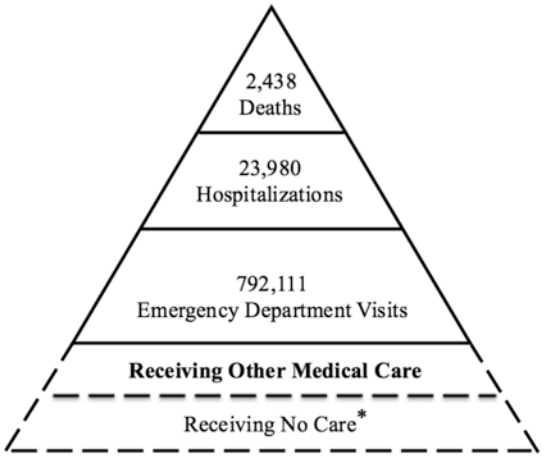
Financial disclosure: No funding specifically for this work was provided. Cheryl K. Zogg, MSPH, MHS, is supported by NIH Medical Scientist Training Program Training Grant T32GM007205. **She is the Primary Investigator of a grant from the Emergency Medical Foundation and American College of Emergency Physicians entitled, "**Understanding Emergency Medicine Providers' Perceptions of the ACA in a Renewed Era of Healthcare Reform: National Survey and Qualitative Mixed-Methods Approach**."**Adil H. Haider, MD, MPH, FACS, is the Primary Investigator of a contract (AD-1306-03980) with PCORI entitled "Patient-Centered Approaches to Collect Sexual Orientation/Gender Identity in the ED,"a Harvard Surgery Affinity Research Collaborative (ARC) Program Grant entitled "Mitigating Disparities Through Enhancing Surgeons' Ability To Provide Culturally Relevant Care," and a collaborative research grant from the Henry M. Jackson Foundation for the Advancement of Military Medicine in conjunction with the Uniformed Services University of the Health Sciences entitled "The Comparative Effectiveness and Provider Induced Demand Collaboration." He is also a co-founder and equity-shareholder of the company Patient Doctor Technologies, Inc., which owns and operates the website www.doctella.com.

References

1. Langlois JA, Marr A, Mitchko J, Johnson RL. Tracking the silent epidemic and educating the public: CDC's traumatic brain injury-associated activities under the TBI Act of 1996 and the Children's Health Act of 2000. J Head Trauma Rehabil. 2005; 20(3):196–204. [PubMed: 15908820]
2. Langlois, J., Rutland-Brown, W., Thomas, K. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths. Atlanta, GA: 2004.
3. Faul, M., Xu, L., Wald, M., Coronado, V. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002-2006. Atlanta, GA: 2010.
4. Schneier AJ, Shields BJ, Hostetler SG, Xiang H, Smith GA. Incidence of pediatric traumatic brain injury and associated hospital resource utilization in the United States. Pediatrics. 2006; 118(2): 483–92. [PubMed: 16882799]
5. Keenan HT, Bratton SL. Epidemiology and outcomes of pediatric traumatic brain injury. Dev Neurosci. 2006; 28(4-5):256–63. [PubMed: 16943649]
6. National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. [Accessed July 4, 2017] National Center for Injury Prevention & Control Traumatic Brain Injury & Concussion. 2017. https://www.cdc.gov/traumaticbraininjury/index.html
7. Taylor AM, Nigrovic LE, Saillant ML, et al. Trends in ambulatory care for children with concussion and minor head injury from Eastern Massachusetts between 2007 and 2013. J Pediatr. 2015; 167(3): 738–44. [PubMed: 26116471]
8. Mannix R, O'Brien MJ, Meehan WP. The epidemiology of outpatient visits for minor head injury: 2005 to 2009. Neurosurgery. 2013; 73(1):129–34. [PubMed: 23615100]
9. Schappert SM, Burt CW. Ambulatory care visits to physician offices, hospital outpatient departments, and emergency departments: United States, 2001-02. Vital Health Stat. 2006; 13(159): 1–66.

10. Ryu WHA, Feinstein A, Colantonio A, Streiner DL, Dawson DR. Early identification and incidence of mild TBI in Ontario. Can J Neurol Sci. 2009; 36(4):429–35. [PubMed: 19650352]
11. Coronado V, McGuire L, Sarmiento K, et al. Trends in traumatic brain injury in the U.S. and the public health response: 1995-2009. J Saf Res. 2012; 43(4):299–307.
12. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F. Seattle Sports Concussion Research Collaborative. Sports- and recreation-related concussions in US youth. Pediatrics J. 2016; 138(1):e20154635.
13. Arbogast KB, Curry AE, Pfeiffer MR, et al. Point of health care entry for youth with concussion within a large pediatric care network. JAMA Pediatr. 2016; 179(7):e160294.
14. Macpherson A, Fridman L, Scolnik M, Corallo A, Guttmann A. A population-based study of paediatric emergency department and office visits for concussions from 2003 to 2010. Paediatr Child Health. 2014; 19(10):543–6. [PubMed: 25587234]
15. Bruns J, Hauser WA. The epidemiology of traumatic brain injury: A review. Epilepsia. 2003; 44(Suppl 1):2–10.
16. Institute of Medicine. Sports-Related Concussions in Youth: Improving the Science, Changing the Culture. Wasington, DC: 2013.
17. Corrigan JD, Selassie AW, Orman JAL. The epidemiology of traumatic brain injury. J Head Trauma Rehabil. 25(2):72–80.
18. [Accessed July 4, 2017] Truven Health Analytics. MarketScan Research Databases. 2017. http://truvenhealth.com/your-healthcare-focus/analytic-research/marketscan-research-databases
19. Adamson D, Chang S, Hansen L. Health Research Data for the Real World: The MarketScan Databases. 2006
20. Rhee D, Salazar JH, Zhang Y, et al. A novel multispecialty surgical risk score for children. Pediatrics. 2013; 131(3):e829–36. [PubMed: 23382436]
21. Statistical Research and Applications Branch, National Cancer Institute. [Accessed July 4, 2017] Joinpoint Trend Analysis Software Version 4.2. 2015. http://surveillance.cancer.gov/joinpoint/
22. Huang, YuB, Tiwari, L., Johnson, R., Feuer, KE. Technical Report # 2007-02: Modeling Population-Based Cancer Survival Trends Using Joinpoint Survival Models. Atlanta, GA: 2007.
23. Dunn, M., Zou, J. Technical Report # 2009-02: : AAPC for the Jointpoint Connect-the-Dots Scenario. Atlanta, GA: 2009.
24. Martinze-Beneito M, Garcia-Donato G, Salmeron D. A Bayesian joinpoint regression with unknown break-points. Ann Appl Stat. 2011; 5(3):2150–68.
25. Smith, J., Medali, C. United States Census Bureau. Current Population Report, P60-250, Health Insurance Coverage in the United States: 2013. Washington, DC: 2014.
26. Tai-Seale M, McGuire TG, Zhang W. Time allocation in primary care office visits. Health Serv Res. 2007; 42(5):1871–94. [PubMed: 17850524]
27. National Center for Health Statistics, Centers for Disease Control and Prevention. Ambulatory Care Use and Physician Office Visits 2017. Jul 4, 2017 https://www.cdc.gov/nchs/fastats/physician-visits.htm
28. National High School Sports Related Injury Surveillance System. [Accessed July 4, 2017] High School Reporting Injury Online (RIO). 2016. www.ucdenver.edu/%0Dacademics/colleges/PublicHealth/%0Dresearch/ResearchProjects/piper/%0Dprojects/RIO
29. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: Implications for prevention. Clin J Sport Med. 2004; 14(1):13–7. [PubMed: 14712161]
30. Kelleher E, Taylor-Linzey E, Ferrigno L, Bryson J, Kaminski S. A community return-to-play mTBI clinic: Results of a pilot program and survey of high school athletes. J Pediatr Surg. 2014; 49(2): 341–44. [PubMed: 24528982]
31. Meehan WP, Mannix R, O'Brien MJ, Collins M. The prevalence of undiagnosed concussions in athletes. Clin J Sport Med. 2013; 23(5):339–42. [PubMed: 23727697]
32. Coronado VG, Haileyesus T, Cheng TA, et al. Trends in sports- and receation-related traumatic brain injuries treated in US emergency departments: The National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001-2012. J Head Trauma Rehabil. 30(3):185–97.

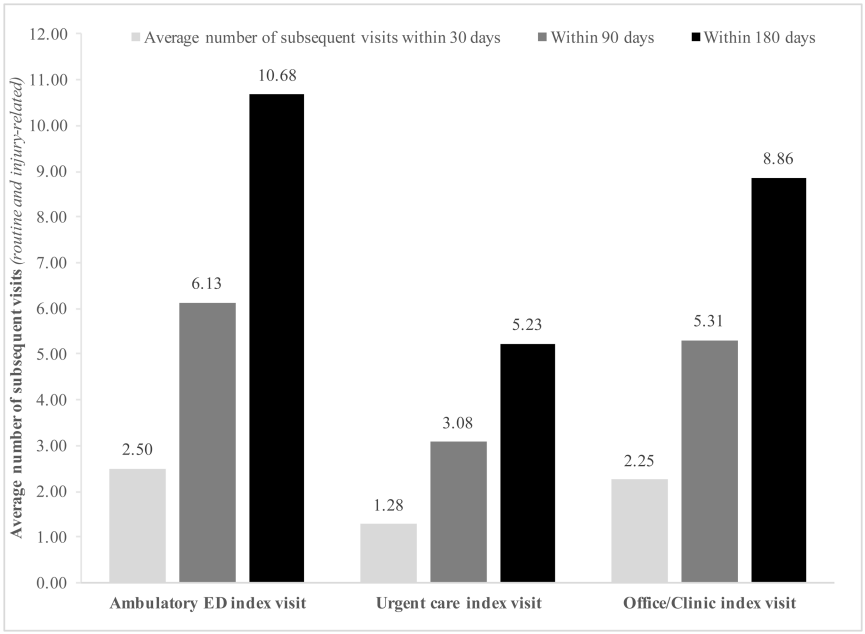
33. Haring RS, Canner JK, Asemota AO, et al. Trends in incidence and severity of sports-related traumatic brain injury (TBI) in the emergency department, 2006-2011. Brain Inj. 2015; 29(7-8): 989–92. [PubMed: 25962926]
34. Harmon KG, Drezner JA, Gammons M, et al. American Medical Society for Sports Medicine position statement: Concussion in sport. Br J Sports Med. 2013; 47(1):15–26. [PubMed: 23243113]
35. Halstead ME, Walter KD. American Academy of Pediatrics. Clinical report--sport-related concussion in children and adolescents. Pediatrics. 2010; 126(3):597–615. [PubMed: 20805152]
36. Jung CS, Zweckberger K, Schick U, Unterberg AW. Helmet use in winter sport activities--attitude and opinion of neurosurgeons and non-traumatic-brain-injury-educated persons. Acta Neurochir (Wien). 2011; 153(1):101–6. [PubMed: 20532575]
37. National Center for Injury Prevention and Control. Implementing Return to Play: Learning from the Experiences of Early Implementers. Atlanta, GA: 2013.
38. Kirschen MP, Tsou A, Nelson SB, Russell JA, Larriviere D. Ethics, Law, and Humanities Committee, a Joint Committee of the American Academy of Neurology, American Neurological Association, and Child Neurology Society. Legal and ethical implications in the evaluation and management of sports-related concussion. Neurology. 2014; 83(4):352–8. [PubMed: 25008394]
39. Lowrey KM, Morain SR. State experiences implementing youth sports concussion laws: Challenges, successes, and lessons for evaluating impact. J Law Med Ethics. 2014; 42(3):290–6. [PubMed: 25264087]
40. Boutis K, Weerdenburg K, Koo E, Schneeweiss S, Zemek R. The diagnosis of concussion in a pediatric emergency department. J Pediatr. 2015; 166(5):1214–20. [PubMed: 25919731]
41. Stevens PK, Penprase B, Kepros JP, Dunneback J. Parental recognition of postconcussive symptoms in children. J Trauma Nurs. 17(4):178–82.
42. Stuart B, Mandleco B, Wilshaw R, Beckstrand RL, Heaston S. Mild traumatic brain injury: Are ED providers identifying which patients are at risk? J Emerg Nurs. 2012; 38(5):435–442. [PubMed: 21774974]
43. Chen C, Shi J, Stanley RM, Sribnick EA, Groner JI, Xiang H. U.S. trends of ED visits for pediatric traumatic brain injuries: Implications for clinical trials. Int J Environ Res Public Health. 2017; 14(4):e414. [PubMed: 28406438]
44. Collins C, Yeates KO, Pommering T, et al. Direct medical charges of pediatric traumatic brain injury in multiple clinical settings. Inj Epidemiol. 2014; 1(1):e13.
45. Chan V, Thurairajah P, Colantonio A. Defining pediatric traumatic brain injury using International Classification of Diseases Version 10 Codes: A systematic review. BMC Neurol. 2015; 15:7. [PubMed: 25648197]
46. Powell JM, Ferraro JV, Dikmen SS, Temkin NR, Bell KR. Accuracy of mild traumatic brain injury diagnosis. Arch Phys Med Rehabil. 2008; 89(8):1550–5. [PubMed: 18597735]
47. Carroll CP, Cochran JA, Guse CE, Wang MC. Are we underestimating the burden of traumatic brain injury? Surveillance of severe traumatic brain injury using centers for disease control International Classification of Disease, ninth revision, Clinical Modification, traumatic brain injury codes. Neurosurgery. 2012; 71(6):1064–70. [PubMed: 22922677]



**There is no estimate for the number of people with non-fatal TBI seen outside of an Emergency Department or hospital setting.*

Figure 1.

Head trauma (traumatic brain injury) pyramid as first conceptualized by the CDC in 2004. Values represent the national burden of deaths, hospitalizations, and emergency department visits among pediatric patients aged 0-17y estimated by the CDC in 2013. Reported deaths represent Record-Axis Condition codes collected by the CDC's National Center for Injury Prevention and Control, non-fatal inpatient hospitalizations were taken from the Agency for Healthcare Research and Quality's (AHRQ's) Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample, and non-hospitalized emergency department vistis were taken from the AHRQ's HCUP Nationwide emergency department Sample—consistent with methods currently employed by the CDC.



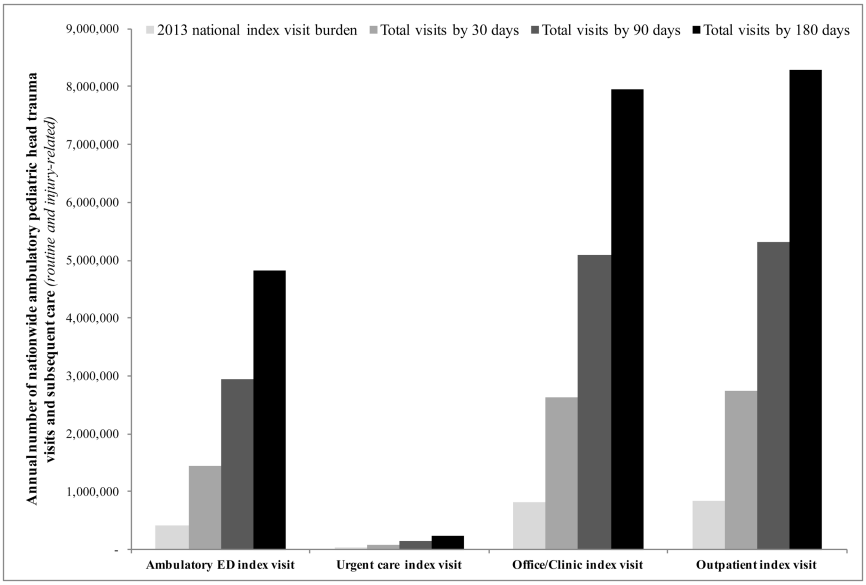
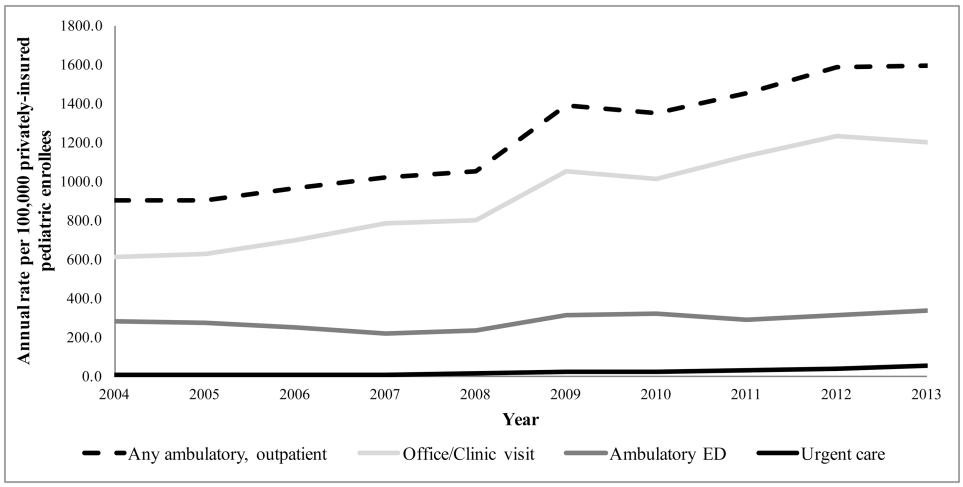
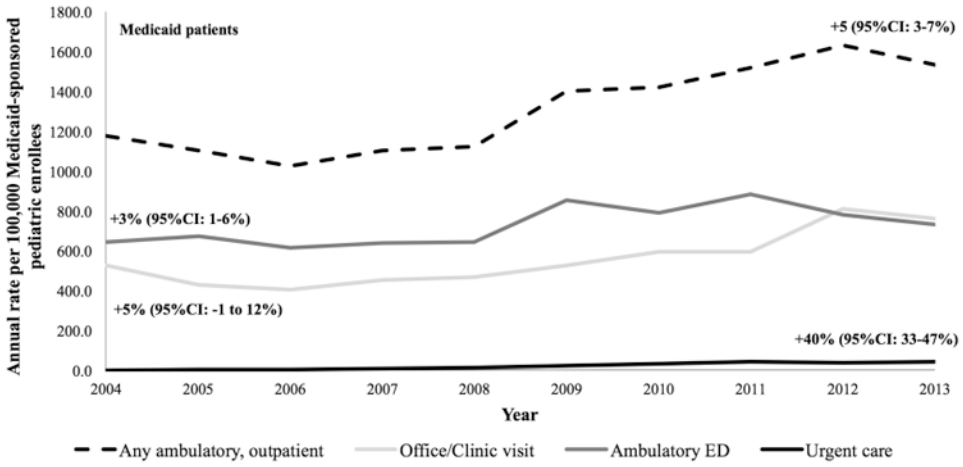


Figure 2.

(**a**) Average (mean) number of subsequent ambulatory visits within 30, 90, and 180 days per index ambulatory pediatric head trauma presentation from 2010-2013. (**b**) Extrapolated 2013 national burden of pediatric index and subsequent ambulatory care visits (routine and injury-related) within 30, 90, and 180 days. Estimates are inclusive of uninsured patients.





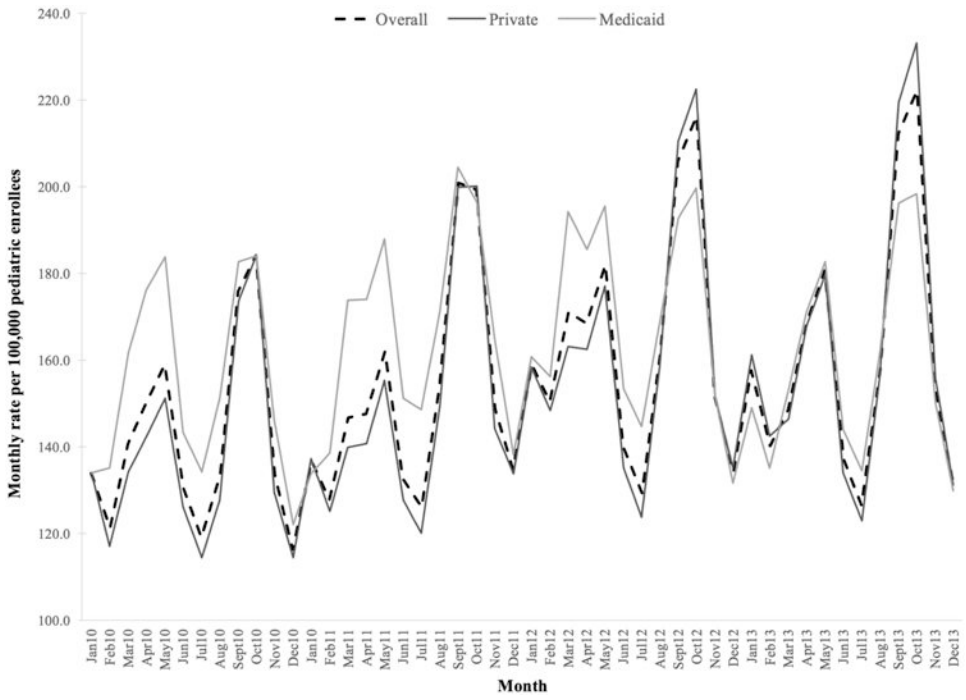


Figure 3.

Annual rates of healthcare-seeking head trauma presentation per 100,000 pediatric enrollees from 2004-2013 and joinpoint-regression results (overall and stratified by index-visit location) among (**a**) privately insured and (**b**) Medicaid patients. Percentages represent the average annual percent change. (**c**) Seasonal variation in outpatient presentation. Results represent monthly rates of healthcare-seeking head trauma visits per 100,000 pediatric enrollees from January 2010-December 2013.

Table 1

Nationwide estimates of the annual burden of pediatric outpatient head trauma visits in 2013 (*uninsured assumed 100% of the national Medicaid rate)*

		2013		Estimated annual number of outpatient visits nationwide	90%CI for national burden		Number of hours of provider time on index presentation
		Observed *n*	Rate per 100,000				
Ambulatory ED	Commercial	36,609	337.5	149,947.9	148,118.6	151,777.1	17,493.9
	Medicaid	33,954	733.2	222,966.1	218,552.3	227,380.0	26,012.7
	Overall	**70,563**	**455.9**	**412,807.4**	**404,511.3**	**421,103.5**	**48,160.7**
Urgent care	Commercial	5,507	50.8	22,569.9	22,294.6	22,845.3	2,633.2
	Medicaid	1,895	40.9	12,437.7	12,191.5	12,683.9	1,451.1
	Overall	**7,402**	**47.8**	**37,233.0**	**36,596.9**	**37,869.1**	**4,343.9**
Office visit	Commercial	130,639	1204.4	535,102.9	528,575.0	541,630.7	62,428.7
	Medicaid	35,174	759.6	230,994.4	226,421.6	235,567.2	26,949.3
	Overall	**165,813**	**1071.3**	**807,427.1**	**794,199.6**	**820,654.6**	**94,199.8**
Any presentation	Commercial	172,755	1592.6	707,576.3	698,944.4	716,208.2	82,550.6
	Medicaid	71,023	1533.8	466,428.6	457,195.1	475,662.1	54,416.7
	Overall	**243,778**	**1575.0**	**1,257,458.9**	**1,235,298.9**	**1,279,618.9**	**146,703.5**
Outpatient only	Commercial	136,146	1255.9	557,672.8	550,869.6	564,476.0	65,061.8
	Medicaid	37,069	800.1	243,432.1	238,613.0	248,251.1	28,400.4
	Overall	**173,215**	**1118.6**	**844,660.1**	**830,796.5**	**858,523.7**	**98,543.7**

Abbreviations: ED – Emergency Department

Table 2

Demographic and injury-specific factors, stratified by place of presentation

	Ambulatory ED		Urgent care		Office/Clinic visit		Overall	
	N = 536,955	**32%**	**N = 31,612**	**2%**	**N = 1,114,530**	**66%**	**N = 1,683,097**	**100%**
Demographic factors								
Age in years								
0-2	175,172	33	8,348	26	237,595	21	421,115	25
3-5	104,239	19	6,114	19	151,087	14	261,440	16
6-10	103,124	19	6,962	22	209,780	19	319,866	19
11-14	80,496	15	5,834	19	250,992	23	337,322	20
15-17	73,924	14	4,354	14	265,076	24	343,354	20
Sex								
Male	327,610	61	19,603	62	683,430	61	1,030,643	61
Female	209,345	39	12,009	38	431,100	39	652,454	39
Insurance								
Commercial	263,873	49	23,424	74	900,799	81	1,188,096	72
Medicaid	273,082	51	8,188	26	213,731	19	495,001	29
Region[a]								
Northeast	52,208	20	2,310	10	167,319	19	221,837	19
Midwest	65,005	25	3,807	16	228,250	25	297,062	25
South	87,911	33	9,305	40	320,450	36	417,666	35
West	54,494	21	7,866	34	167,252	17	229,612	19
Unknown	4,255	2	136	1	17,528	2	21,919	3
Year								
2004	37,049	7	376	1	48,604	4	86,029	5
2005	38,950	7	459	2	45,746	4	85,155	5
2006	33,936	6	652	2	45,442	4	80,030	5
2007	36,212	7	1,166	4	74,798	7	112,176	7

	Ambulatory ED		Urgent care		Office/Clinic visit		Overall	
	N = 536,955	**32%**	**N = 31,612**	**2%**	**N = 1,114,530**	**66%**	**N = 1,683,097**	**100%**
2008	42,095	8	1,874	6	88,872	8	132,841	8
2009	64,724	12	3,125	10	129,414	12	197,263	12
2010	66,881	13	3,991	13	141,738	13	212,610	13
2011	69,209	13	5,112	16	172,226	16	246,547	15
2012	77,336	14	7,455	24	201,877	18	286,668	17
2013	70,563	13	7,402	23	165,813	15	243,778	15
Injury-specific factors								
Loss of Consciousness								
No	522,280	97	31,228	99	1,071,386	96	1,624,894	96
Yes	14,675	3	384	1	43,144	4	58,203	4
Charlson Comorbidity Index								
0	524,413	98	31,419	99	1,091,667	98	1,647,499	98
≥1	12,542	2	193	1	22,863	2	35,598	2
Pediatric Surgical Risk Score								
0	295,373	55	18,811	60	519,972	47	834,156	50
1-2	114,433	21	4,963	16	157,019	14	276,415	16
3-4	122,658	23	7,731	25	421,082	38	551,471	33
≥5	4,491	1	107	<1	16,457	2	21,055	1
Max. Head Abbreviated Injury Scale								
0	38	0	1	<1	919	<1	958	<1
1	10,293	2	558	2	25,471	2	36,322	2
2	519,238	97	30,842	98	1,056,323	95	1,606,403	95
3	4,755	1	107	<1	18,981	2	23,843	1
4	2,222	<1	66	<1	10,941	1	13,229	1
5	359	<1	30	<1	1,611	<1	2,000	<1
6	50	<1	8	<1	281	<1	339	<1
Overall Injury Severity Score								

	Ambulatory ED		Urgent care		Office/Clinic visit		Overall	
	N = 536,955	**32%**	**N = 31,612**	**2%**	**N = 1,114,530**	**66%**	**N = 1,683,097**	**100%**
<4	10,331	2	559	2	26,390	2	37,280	2
4-8	513,431	96	30,732	97	1,038,232	93	1,582,395	94
9-15	10,298	2	215	1	36,076	3	46,589	3
16-24	2,423	1	68	<1	11,750	1	14,241	1
≥25	472	<1	38	<1	2,082	<1	2,592	<1

Abbreviations: ED – Emergency Department

[a]MarketScan Medicaid databases do not include region information. Results are shown for commercial patients.

Table 3

Variations in CDC-defined head trauma diagnoses on index presentation, stratified by place of presentation, and the 20 most prevelent primary diagonses for subsequent ambulatory visits within 30 and 180 days

	Ambulatory ED[a]		Urgent care		Office/Clinic Visit		Overall	
	536,955	**32%**	**31,612**	**2%**	**1,114,530**	**66%**	**1,683,097**	**100%**
Presenting TBI diagnosis[c]								
Unspecified head injury	461,323	86	25,167	80	794,353	71	1,280,843	76
Concussion	93,306	17	6,685	21	344,162	31	444,153	26
Other or unspecified intracranial injury	32,320	6	1,065	3	83,836	8	117,221	7
Closed fracture base of skull	1,990	<1	36	<1	8,595	1	10,621	1
Other closed skull fracture	1,792	<1	61	<1	8,642	1	10,495	1
Closed fracture vault of skull	1,655	<1	50	<1	7,816	1	9,521	1
Intracranial hemorrhage	1,512	<1	31	<1	7,952	1	9,495	1
Cortex/Cerebral contusion or laceration	1,062	<1	42	<1	3,912	<1	5,016	<1
Closed fracture skull/face	164	<1	8	<1	1,052	<1	1,224	<1
Shaken-infant syndrome	65	<1	2	<1	1,068	<1	1,135	<1
Injury to optic chiasm/pathway/visual cortex	101	<1	11	<1	482	<1	594	<1
Open fracture vault of skull	55	<1	1	<1	354	<1	409	<1
Other open skull fracture	60	<1	1	<1	266	<1	327	<1
Open fracture base of skull	46	<1	1	<1	215	<1	262	<1
Open fracture of the skull or face	14	<1	3	<1	112	<1	129	<1

20 most prevalent primary diagnoses for subsequent visits within 30 days (% of visits)			**Within 180 days** (% of visits)		
V20.2	Routine child health exam	10%	V20.2	Routine child health exam	7%
784.0	Headache[d]	4%	462.×	Acute pharyngitis	2%
310.2	Post-concussion syndrome[d]	3%	V04.81	Influenza vaccine	1%
723.1	Cervicalgia[d]	2%	748.0	Headache[d]	1%
462.×	Acute pharyngitis	2%	310.2	Post-concussion syndrome[d]	1%
920.×	Contusion of face/scalp/neck[d]	2%	465.9	Acute respiratory infection NOS[b]	1%
V04.81	Influenza vaccine	2%	723.1	Cervicalgia[d]	1%

	Ambulatory ED[a]		Urgent care		Office/Clinic Visit		Overall	
	536,955	**32%**	**31,612**	**2%**	**1,114,530**	**66%**	**1,683,097**	**100%**
959.09	Face and neck injury[d]	2%	780.60	Fever NOS[b]				1%
837.0	Sprain of neck[d]	1%	920.×	Contusion of face/scalp/neck[d]				<1%
780.2	Syncope and collapse[d]	1%	701.6	Acne				<1%
465.9	Acute respiratory infection NOS[b]	1%	382.9	Otitis media				<1%
873.0	Open wound of the scalp[d]	1%	314.01	Attention deficit disorder with hyperactivity[d]				<1%
739.1	Cervical somatic dysfunction[d]	1%	034.0	Strep throat				<1%
873.42	Open wound of forehead[d]	1%	786.2	Cough				<1%
780.60	Fever NOS[b]	1%	739.1	Cervical somatic dysfunction[d]				<1%
701.6	Acne	1%	837.0	Sprain of neck[d]				<1%
780.39	Convulsions NOS[b,d]	1%	780.2	Syncope and collapse[d]				<1%
382.9	Otitis media	1%	079.99	Viral infection NOS[b]				<1%
314.01	Attention deficit with hyperactivity[d]	1%	789.00	Abdominal pain at unspecified site				<1%
780.4	Dizziness and giddiness[d]	1%	V70.0	Routine medical exam				<1%

Abbreviations:

[a]ED – Emergency Department,

[b]NOS – not elesewhere specified

[c]Each vist had multiple diagnoses; diagnoses are not mutually excluded.

[d]Diagnoses consistent with head trauma recovery (*e.g.* contusion, open wound of the head) and associated sequelae (*e.g.* headache, post-concussion syndrome)