Factors Associated With Repeat Emergency Department Visits in a State-wide Cohort of Pediatric Patients With Mild Traumatic Brain Injury

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Objective: To describe demographic, injury, and clinical characteristics of pediatric patients treated in the ED for mild traumatic brain injury (mTBI), and to evaluate characteristics associated with mTBI-related return emergency department (ED) visit within 1 month of initial presentation.

Methods: Retrospective cohort study from April 1, 2012, to September 30, 2017, of children 19 years or younger presenting to any Maryland ED for mTBI identified in the Maryland Health Services Cost Review Commission database using ICD-9/10 codes. Demographic, injury, and clinical characteristics of individuals were collected. The primary outcome was mTBI-related return ED visit within 4 weeks. Multiple logistic regression tested the associated of individual demographic, injury, and clinical characteristics with mTBI-related return ED visit.

Results: There were 25,582 individuals who had an ED visit for mTBI, of which 717 (2.8%) returned to the ED within 4 weeks and 468 (1.8%) within 1 week with a mTBI-related diagnosis. In multivariable logistic regression analyses, public insurance (adjusted odds ratio [aOR], 1.44; 95% confidence interval [CI], 1.21–1.72) and female sex (aOR, 1.34; 95% CI, 1.15–1.56) were associated with increased odds of return to the ED within 4 weeks. Age younger than 2 years (aOR, 0.39; 95% CI, 0.21–0.72) was associated with decreased odds of return visit. There was a trend toward decreased odds of return patients receiving computed tomography head imaging (aOR, 0.86; 95% CI, 0.74–1.01).

Conclusions: Although return to the ED for mTBI-related complaints is uncommon, girls, older children, and publicly insured individuals may be at increased risk. Future targeted study may identify areas to improve access to appropriate longitudinal care and justify ED programs to better coordinate follow-up for mTBI.

Key Words: mild traumatic brain injury, concussion, return ED visit

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Pediatric mild traumatic brain injury (mTBI) remains at the forefront of public consciousness, and an unprecedented number of children are seeking care for these injuries.[1,2] The true incidence of mTBI in children is uncertain, because they may be evaluated by a variety of practitioners ranging from a school athletic trainer to any number of health care providers along the care continuum. It has been reported that the majority of children with mTBI are evaluated in outpatient clinic settings, however there are more than one million emergency department (ED) visits for pediatric mTBI per year.[2]

Importance

Brain injuries often require longitudinal follow-up for symptom management. One study in the adult literature found that 5% of patients who suffered a traumatic brain injury (TBI) returned to the ED within 72 hours of injury with "postconcussion syndrome" or "pain."[3] In contrast, another study of adults with mTBI identified that less than half of these patients received any outpatient follow-up within 3 months of the injury.[4] The pediatric patient population that uses the ED and outpatient care for mTBI care has been described within a single health care system[5]; however, little is reported about the individuals who return to the ED for follow-up visits related to this initial injury. Frequency and justification for a return visit to the ED in pediatric patients with mTBI is not well described. Prolonged symptoms and state laws requiring clearance to return to activity by a qualified professional[6] may both motivate a return ED visit; however, these require longitudinal assessments best provided in an outpatient setting, because the ED is not optimally structured to provide this type of care. Identification of patients who are more likely to return to the ED may allow providers to target their interventions and counseling to reduce ED visits.

Goals of This Investigation

The objective of our study was to describe the demographic, injury, and clinical characteristics of pediatric mTBI patients presenting across all Maryland EDs and to determine associations with mTBI-related return to the ED. The primary outcome was mTBI-related return ED visit within 4 weeks of initial injury.

METHODS

Data Source and Study Population

Using the Maryland Health Services Cost Review Commission database,[7] we performed a population based, retrospective cohort study of children (0–19 years) evaluated and discharged from an ED with a mTBI diagnosis from April 1, 2012, through September 30, 2017. The Health Services Cost Review Commission is a publicly available, claims-based resource and is generated through mandatory, quarterly reporting from all hospital-affiliated inpatient and outpatient visits in the state, capturing approximately 800,000 inpatient and 5 million outpatient and ED visits each year. Individuals are assigned a unique identifier and, therefore, can be followed over time.

We identified all children presenting to an ED with a diagnosis of mTBI or concussion using 33 International Classification of

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Diseases-9 (ICD-9) and ICD-10 codes (complete lexicon in Supplemental Table 1, http://links.lww.com/PEC/A688). For children with multiple TBI-related visits, we identified the index encounter as the first recorded encounter during the study period. Mechanism of injury included in the data set was preclassified using the Centers for Disease Control external cause of injury matric codes.[8] For analyses, we combined the mechanisms "motor vehicle collisions," "pedal cyclist," and "pedestrian and other transport-related mechanisms" into a single group called "transport." We excluded children with mechanisms of injury suggestive of anoxic or penetrating brain injury, diagnosis of intracranial hemorrhage, skull fracture, a high severity score, or requiring inpatient admission as these were considered to represent more severe TBI (Fig. 1). The study period included a 3-month run-in at the start of the study to reduce misclassification of an index visit and allow sufficient follow-up time such that all individuals at the end of the study were observed for at least 4 weeks.

Outcome Definitions

The primary outcome was a mTBI-related return visit to the ED, defined as a subsequent ED visit within 4 weeks of the index ED presentation. This time frame for a return visit was based on prior studies describing typical duration of mTBI symptoms.[9] Return visits were identified using the same ICD codes as the index visit with the addition of the "postconcussive syndrome" diagnoses and exclusion any codes specified as "initial encounter." Secondary outcomes included mTBI-related return ED visit within 1 week. We also evaluated both 1- or 4-week mTBI-related ED visits with the addition of headache-related ICD codes. Individuals with headache-related ICD codes were identified from the index cohort meeting the study definition for mTBI. To confirm that there were no other major causes for an ED return visit, the principal and first 5 diagnosis codes listed for each individual meeting criteria for the mTBI-related ED return were reviewed.

Statistical Analyses

Demographic, injury, and clinical characteristics were summarized using univariate statistics. Multivariable logistic regression was used to evaluate the association of selected demographic, injury, and clinical characteristics identified *a priori* with odds of mTBI-related ED return visit. Demographic factors included sex, age (categories <2, 2–4, 5–9, 10–14, 15–19 years[10] determined using Centers for Disease Control injury reports[10] and combining all children younger than 2 years similar to the Pediatric Emergency Care Applied Research Network head injury study[11]), race (non-Hispanic White, non-Hispanic African-American, other), insurance status (private, Medicaid, self-pay, other), and zip code income quintile (high, med-high, med, med-low, low) based on

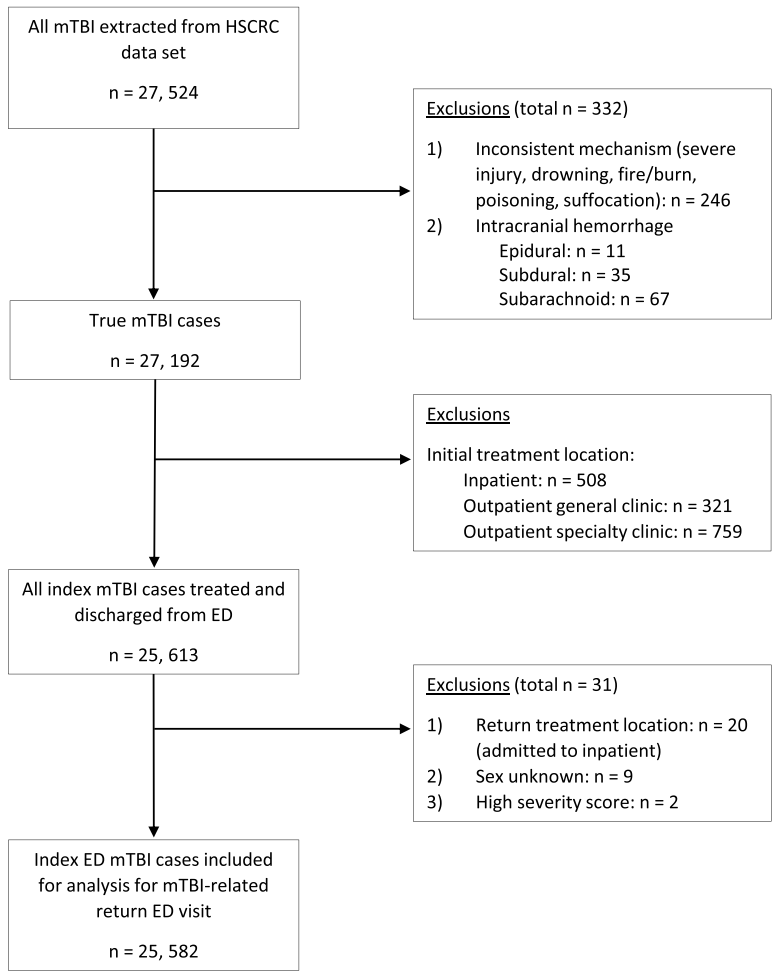

FIGURE 1. Study flow diagram. Defining ICD-9/10 codes included in supplemental material.

patient's residential address as an indicator of socioeconomic status. Injury and clinical characteristics included mechanism of injury (struck, fall, transport-related, other/not classified), receipt of head computed tomography (CT) during the index mTBI ED visit (yes/no) and loss of consciousness (yes/no). Unadjusted (univariable) odds ratios (ORs) and 95% confidence intervals (CI) were calculated, in addition to adjusted (multivariable) ORs, accounting for key demographic, injury, and clinical characteristics. A sensitivity analysis excluding individuals with diagnosis codes related to mTBI but with vague explanation of severity of injury was also performed (Supplemental Table 4, http://links.lww.com/PEC/A691). A *P* value less than 0.05 was considered statistically significant. All analyses were performed using Stata Version 14.1 (StataCorp, College Station, TX).

This study was approved by the Johns Hopkins Institutional Review Board.

RESULTS

Cohort Characteristics

We identified 25,613 children who were evaluated and discharged from a Maryland ED with a diagnosis of mTBI (index mTBI ED visit) during the study period. The analytic sample was comprised of 25,582 children who met all inclusion criteria and had complete covariate data (Fig. 1). Very few children with a mTBI-related ED return visit required admission (20/25,582, 0.08%). A total of 717 children (2.8%) had an mTBI-related ED return visit within 4 weeks of the index mTBI visit; 468 individuals (1.8% total, 65% of all children with return visits) returned within 1 week.

On expanded review of the other principal and secondary diagnosis codes listed for individuals in the ED return group, greater than 98% of codes pertained to headache or concussion. Full cohort characteristics are summarized in Table 1.

Demographics

Overall, the baseline characteristics were similar between groups. Key differences included a higher proportion of children younger than 2 years (44% vs 40%) or older than 15 years (42% vs 35%) with mTBI-related return ED visits. Additionally, there were more non-Hispanic White (63.9% vs 59.7%), and children public insurance (37% vs 32%) in the return group.

Injury Characteristics

Overall, "struck" as the most common specified mechanism of injury. Sport-related injuries accounted for 22.4% (n = 5728) of all index mTBI ED visits, with 49% of these injuries being classified into the "struck" mechanism of injury. An injury severity score (ISS) was calculated for 77.4% of the index cohort, of which 99% were classified as "mild" (ISS score <9). Compared with children who did not have a return ED visit, a higher proportion of the mechanism of injury was identified as "struck" (36% vs 31%) in individuals with a mTBI-related ED return visit. Sport-related injuries accounted for 29% of overall return visits.

Clinical Characteristics

Reported loss of consciousness was low (15%), and seizures were rare (0.4%). Head CT was common, performed in 47% of index mTBI ED visits. There were 37 (0.1%) individuals who had intravenous or intramuscular intervention, and 88 (0.3%) individuals had a concomitant diagnosis of migraine in the index ED visit. In the return visit, 1 individual required intravenous or intramuscular intervention, and 55 individuals had a head CT, all of whom were discharged home from the emergency department. Only 2 individuals with migraines had a return mTBI or headache-related ED visit within 4 weeks.

Associations With mTBI-related Return Visit

Results of the multivariable logistic regression analysis evaluating the odds of mTBI-related ED return visit are presented in Figure 2 (full results of the unadjusted and multivariable logistic regression model are available in Supplemental Table 2, http://links.lww.com/PEC/A689).

Demographics

After adjustment, female sex (aOR, 1.34; 95% CI, 1.15–1.56) was associated with higher odds of an mTBI-related ED return visit within 4 weeks. The youngest age category (<2 years: aOR, 0.39; 95% CI, 0.21–0.72) and African-American race (aOR, 0.75; 95% CI, 0.62–0.91) were associated with lower odds of mTBI-related ED return visit within 4 weeks. Although income quintile was not associated with a higher odds of return, compared with those with private insurance, public insurance had a higher odds (aOR, 1.44; 95% CI, 1.21–1.72) and self-pay had a lower odds (aOR, 0.51; 95% CI, 0.31–0.84) of mTBI-related ED return visit.

Injury Characteristics

Children with a "fall" mechanism (aOR, 0.76; 95% CI, 0.62–0.94) or "transport" mechanism (aOR, 0.71; 95% CI, 0.52–0.97) had lower odds of mTBI-related ED return visit versus "struck." Other mechanisms of injury (aOR, 1.08; 95% CI, 0.87–1.34) were not significantly associated with mTBI-related ED return visits.

Clinical Characteristics

There was a trend toward lower odds of mTBI-related ED return visit in patients who received a head CT at the index mTBI ED visit (aOR, 0.86; 95% CI, 0.74–1.01), and loss of consciousness was not associated with return (aOR, 0.81; 95% CI, 0.61–1.07).

Secondary Analyses

The direction and magnitude of observed associations of individual-level characteristics were similar when evaluating the odds of mTBI-related ED return visit within 1 week of index mTBI ED visit (Fig. 2, Supplemental Table 2, http://links.lww.com/PEC/A689). When headache-related diagnoses were included in the definition for ED return, a total of 468 (1.8%) and 220 (0.9%) additional individuals had an ED return visit at 4 weeks and 1 week, respectively. Risk factors for mTBI-related ED return visit within one or 4 weeks did not differ appreciably from the aforementioned primary analyses (Supplemental Table 3, http://links.lww.com/PEC/A690).

LIMITATIONS

This retrospective study is subject to the quality and consistency of the data, as with any other administrative database. However, this study was a population-based investigation with relatively complete patient covariate data. We presumed accurate identification of an index mTBI with our claims library, and that the return visit represented continued symptoms, as opposed to a new injury. The individual's Glasgow Coma Scale and reasons for CT utilization could not be determined with this data set. This database also does not contain urgent care or private primary care clinics, and we postulate that many children are being evaluated, following up, and are obtaining clearance to return to play in these settings. Finally, this study did not assess rationale for return, for example

TABLE 1. Demographic, injury, and clinical characteristics of children presenting to an ED with mTBI, overall and with mTBI-related ED return visit within 4 weeks; univariate analysis

	Overall (N = 25,582)	No mTBI-related return ED visit within 4 weeks (n = 24,865)	mTBI-related return ED visit within 4 weeks (n = 717)	*P*
Demographic characteristics				
Male, n (%)	15,376 (60.1)	14,996 (60.3)	380 (53.0)	<0.001
Age group, n (%)				
<2 y	10,161 (39.7)	9843 (39.6)	318 (44.4)	<0.001
2–4 y	840 (3.3)	829 (3.3)	11 (1.5)	
5–9 y	1549 (6.1)	1536 (6.2)	13 (1.8)	
10–14 y	3965 (15.5)	3894 (15.7)	71 (9.9)	
15–19 y	9067 (35.4)	8763 (35.2)	304 (42.4)	
Race/ethnicity, n (%)				0.045
Non-Hispanic White	15,295 (59.8)	14,837 (59.7)	458 (63.9)	
Non-Hispanic African-American	6835 (26.7)	6671 (26.8)	164 (22.9)	
Hispanic	436 (1.7)	429 (1.7)	7 (1.0)	
Asian/Pacific	360 (1.4)	352 (1.4)	8 (1.1)	
Non-Hispanic Native American	333 (1.3)	327 (1.3)	6 (0.8)	
Other	2323 (9.1)	2249 (9.0)	74 (10.3)	
Insurance, n (%)				<0.001
Private	14,603 (57.1)	14,211 (57.2)	392 (54.7)	
Medicaid/care	8284 (32.4)	8016 (32.2)	268 (37.4)	
Self-pay	1378 (5.4)	1361 (5.5)	17 (2.4)	
Other	1317 (5.2)	1277 (5.1)	40 (5.6)	
Income quintile, n (%)				0.102
Low	4538 (17.7)	4398 (17.7)	140 (19.5)	
Med-low	4352 (17.0)	4245 (17.1)	107 (14.9)	
Med	5425 (21.2)	5293 (21.3)	132 (18.4)	
Med-high	6011 (23.5)	5827 (23.4)	184 (25.7)	
High	5256 (20.6)	5102 (20.5)	154 (21.5)	
Injury characteristics				
Mechanism, n (%)				<0.001
Struck	7944 (31.1)	7685 (30.9)	259 (36.1)	
Fall	6900 (27.0)	6754 (27.2)	146 (20.4)	
Transport*	2349 (9.2)	2298 (9.2)	51 (7.1)	
Other/ not classified†	8389 (32.8)	8128 (32.7)	261 (36.4)	
ISS, n (%)‡				0.383
<9	19,618 (99.1)	19,080 (99.1)	538 (98.5)	
9–15	178 (0.9)	170 (0.9)	8 (1.5)	
>15	11 (0.1)	11 (0.1)	0 (0.0)	
Clinical characteristics				
Received head CT, n (%)	12,094 (47.3)	11,786 (47.4)	308 (43.0)	0.019
Loss of consciousness, n (%)	3929 (15.4)	3837 (15.4)	92 (12.8)	0.057
IV/IM intervention, n (%)	37 (0.1)	36 (0.1)	1 (0.1)	1.000
Abuse, n (%)	16 (0.1)	14 (0.1)	2 (0.3)	0.073

* Includes motor vehicle collisions, pedal cyclist, pedestrian, and other transport-related mechanisms.

† Includes other, not classifiable, unspecified, and missing.

‡ Excludes 5775 (22.6%) children with missing ISS of which 5604 did not return to ED within 4 weeks and 171 who returned to ED within 4 weeks.

referral back to the ED by another provider for additional imaging or subspecialty care, which in our clinical experience accounts for some return ED visits in children with mTBI. Although some return ED visits may be clinically indicated, less than 0.08% of return patients in our population required admission, intravenous fluids, or neuroimaging suggesting that the vast majority of our return population would likely be safely for cared for in the outpatient clinic.

DISCUSSION

We identified nearly 5000 children per year evaluated in Maryland EDs for mTBI. To our knowledge, this is the first

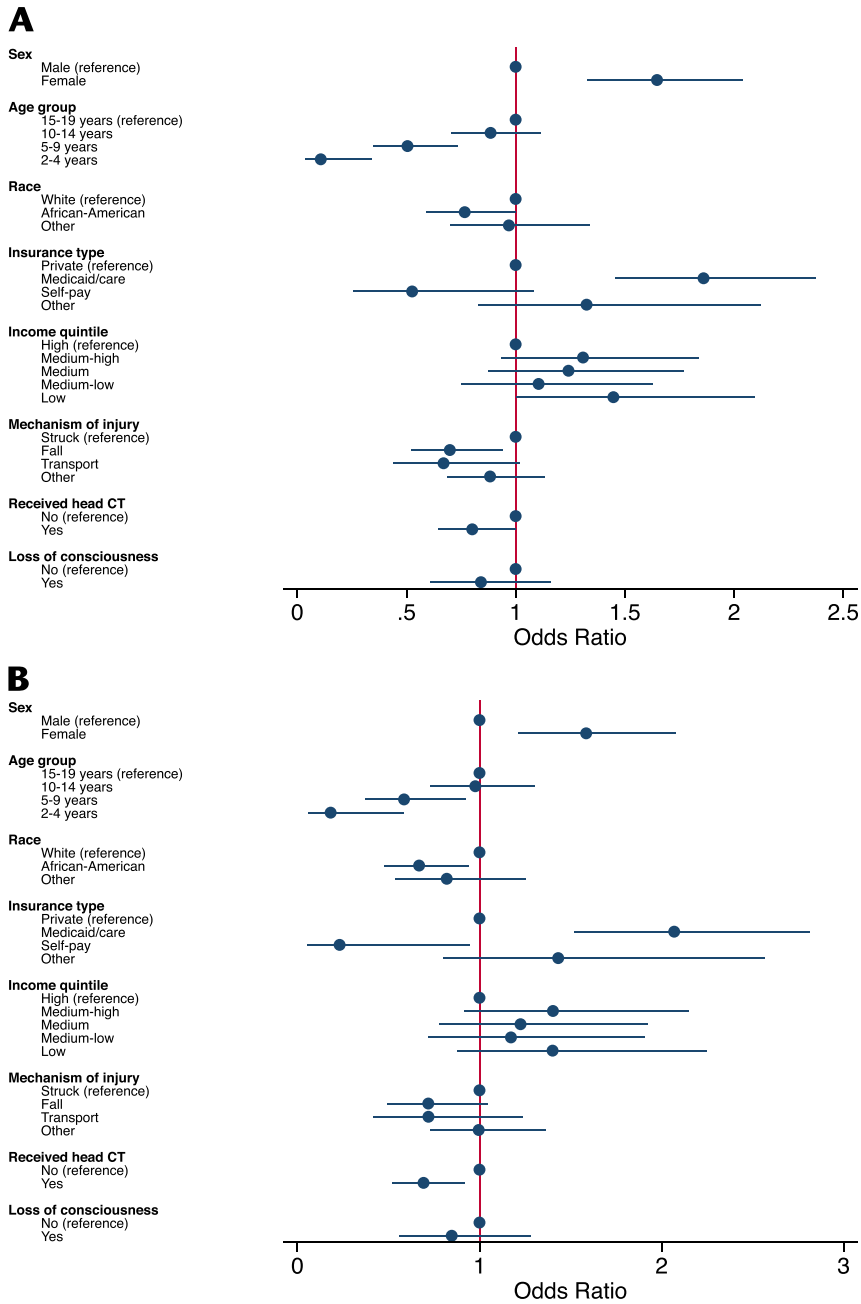

FIGURE 2. Multivariable logistic regression evaluating the odds of mTBI-related return to ED with mTBI-related ICD-9/10 codes within 4 weeks (A) and 1 week (B) by selected risk factors among children presenting to the ED with mTBI.

population-based study to temporally follow up pediatric patients for return ED visits for continued mTBI-related symptoms and to identify associated risk factors. Despite previous studies describing prolonged symptoms occurring in approximately 30% of children with concussion,[12] return to the ED was relatively uncommon in our study population (2.8%), although this did represent more than 100 children per year. These visits may be related to the combined effect of persistent symptoms and the absence of proper follow-up with, for example, a sports medicine specialist, family physician, or pediatrician. Although the study population reflected the racial and ethnic distribution of the State of Maryland,[13] ED return visits were more common in female patients, those with public insurance, and older teenagers.

Pediatric mTBI results in an important burden of injury, although the true overall incidence is difficult to ascertain as patients may seek care in a variety of settings or not at all.[14] Notably, the incidence of ED presentation in our study was 3.8 events per 1000 children in Maryland,[13] which is nearly half of the reported incidence of fracture, a well-recognized childhood injury.[15] In addition to known increasing cases of head trauma in children,[16] this incidence may reflect persistent focus of national public health efforts, such as the CDC Heads Up campaign,[17] to improve community

awareness of head injuries, the potential complications thereof, and importance of treatment.

Sex differences in mTBI is an area of active research. Consistent with previous epidemiologic descriptions of mTBI, our population was 60% boys.[18] However, female sex was associated with a 23% higher odds of return ED visit. One study describing sport-related concussion in high school athletes found differences in symptoms at the time of injury but no difference in time to recovery or return to play between female and male athletes.[19] Other studies have proposed increased severity of symptoms and delayed recovery in female patients attributable to biologic differences between sexes (eg, ranging from differences in mitochondrial function to comparatively weak neck musculature), as well as cultural pressures resulting in underreporting of mTBI in girls.[18] Sex differences in patients with prolonged concussion syndromes are also described, including a longer time interval from injury to presentation for care associated with prolonged concussion syndrome.[20] The true disparity in sex and gender in natural history and course of mTBI remains unclear and is an opportunity for future investigation.

Publicly insured patients were more likely to have a return ED visit in our study population (57% higher odds compared with those with private insurance). This is consistent with trends in national H-CUP data describing increased utilization of EDs by publicly insured individuals in general.[21] Over 32% of our cohort were publicly insured, which is a higher proportion than the 25% of children covered by Medicaid in Maryland overall.[22] Publicly or underinsured youth may represent a vulnerable population that would particularly benefit from the establishment of a medical home for mTBI care. Given local laws in the United States, we also postulate that a need for clearance to return to activity after mTBI may motivate ED return visits,[23] although many youth return to play without clearance despite being symptomatic.[24] Specific to sport-related mTBI (nearly a quarter of our index mTBI-related ED visit population), those from underserved communities may not have access to an athletic trainer,[25] thus may seek follow-up and clearance in settings such as the ED. Fewer return visits in patients with self-pay may reflect the financial burden of ED visits.

The decreased odds of return visit in the African American population in our study is of uncertain cause, however, may reflect racial disparities that exist both in general health care utilization and in specifically as it relates to mTBI.[26] For example, one study of sport-related head injury found that Black children were less likely than White children to receive the diagnosis of "concussion" in the ED. This disparity may impact anticipatory guidance, including return precautions.[27] Another study demonstrated a knowledge gap, in which African American teenage athletes had decreased concussion awareness and ability to identify symptoms. This difference in understanding may also result in decreased presentation for continued mTBI-related symptoms.[28]

The trend of older teenagers returning to the ED in our study may also reflect the overall decreased utilization of primary care pediatricians in late adolescence that has been previously described.[29] Increased access to primary care, regardless of insurance type, is reported in the nation's youngest patients (<24 months), and decreases with older age.[30] Access to primary care can decrease ED utilization.[31]

Interestingly, head CT utilization was common (approximately 47%) despite low ISS scores, which does not appear in keeping with current trends to reduce radiation exposure to patients at low risk for clinically important TBIs identified by the Pediatric Emergency Care Applied Research Network Head Injury study.[11] The trend toward decreased return to the ED in patients receiving a head CT on the initial ED visit may be because of parental and patient reassurance with negative head imaging and provider confidence in counseling that there is no intracranial hemorrhage, and therefore no urgent need to return to the ED if symptoms persist.[32] The rate of head CT was higher than expected, although previously reported rates of head CT use in pediatric mTBI have been variable.[33] The population in our study included individuals of all pediatric ages and care was provided in emergency departments across the spectrum of health care facilities, which may explain some of this difference. Head CT utilization rates in this population is an important area for future investigation.

The population that we identified with increased odds of mTBI-related ED return visit is similar to previously described populations at risk for prolonged mTBI-related symptoms.[34] Our findings provide further evidence to support targeting this population as we understand more of the morbidity associated with prolonged symptoms and failure to obtain longitudinal care for mTBI.[35–37] Even if these return visits represent an intercurrent, second injury, the population still deserves focus, as repeat head injury is more likely to result in prolonged recovery.[9] Although rare, a repeat head injury in close temporal proximity to the initial event has been associated with "second impact syndrome" which can be life threatening.[38] In addition, the potential cumulative impact of multiple mild injuries to the head is being increasingly understood, including the development of chronic traumatic encephalopathy (CTE).[39] Therefore, patients with multiple visits to the ED with mTBI-related symptoms are a group in need of critical counseling and appropriate follow-up to reduce potential morbidity and mortality that can be associated with mTBI.

In summary, thousands of children are evaluated in Maryland EDs each year with mTBI, and a small proportion have a mTBI-related repeat ED visit within one month of the initial injury. Given the frequency of prolonged mTBI symptoms in children, it is important to determine if and where these individuals are receiving follow-up care. All children evaluated in the ED should receive anticipatory guidance about continued symptoms and outpatient follow-up. The population that we have identified with increased odds of mTBI-related return visits may provide an opportunity for EDs to partner with primary care and subspecialty providers. Such coordinated efforts may optimize longitudinal care in an effort to minimize time to recovery and improve resource utilization in our complex health care system. These results may also inform future studies on ED management and particularly discharge counseling for pediatric patients with mTBI.

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