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Emergency Department Evaluation of Traumatic Brain Injury in the United States, 2009–2010

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Abstract

Objective—Determine the dimensions of traumatic brain injury (TBI) evaluation in U.S. emergency department (EDs) to inform potential application of novel diagnostic tests.

Setting—United States EDs.

Participants—National Hospital Ambulatory Medical Care Survey of ED visits in 2009 and 2010 where TBI was evaluated (1) and diagnosed clinically, or (2) with head CT scan.

Design—Retrospective cross-sectional.

Results—TBI was evaluated during 4.8 (95% CI: 4.2–5.4) million visits/year; and head CT scan was performed in 82% of TBI evaluations (3.9 [95% CI: 3.4–4.4] million visits/year). TBI was diagnosed in 52% of evaluations (2.5 [95% CI: 2.1–2.8] million visits/year). Among those who received head CTs, 9% had CT evidence of traumatic abnormalities. Among patients evaluated for TBI who had a Glasgow Coma Scale recorded, 94.5% were classified as mild TBI, 2.1% as moderate TBI and 3.5% as severe TBI. Among patients with ICD9-C-M codes permitting the calculation of Head AIS scores 9.0%, 85.0%, 2.5%, 3.2%, 0.3% and 0% had Head AIS scores of 1,2,3,4,5,6 respectively. Of patients evaluated for TBI, 31% had other head/face/neck injuries; 10% had spine and back injuries; 7% had torso injuries; and 14% had extremity injuries.

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Conclusion—The ED is the main gateway to medical care for millions of patients evaluated for TBI each year. Novel diagnostic tests are need to improve ED diagnosis and management of TBI.

Introduction

Although TBI remains an important cause of death and disability in the United States,[1] objective diagnosis and accurate determination of TBI prognosis remains challenging. Numerous studies have investigated the use of novel diagnostics (including circulating biomarkers[2–6] and quantitative brain electrical activity[7]) to improve the accuracy, timeliness and cost-effectiveness of diagnosing TBI in the ED. However, the target population of these studies (i.e. patients evaluated for TBI in EDs) has not been described in sufficient detail.

Prior studies have described ED patients diagnosed with TBI, but not the entire population of ED patients evaluated for TBI.[8–12] Estimates from the Centers for Disease Control and Prevention (CDC) identified 2.5 million emergency department (ED) visits, hospitalizations, or deaths associated with TBI in 2010.[8] This estimate includes only patients diagnosed with TBI and does not account for numerous patients presenting with traumatic injury who were evaluated for TBI with a head CT scan but were not ultimately diagnosed with TBI. These patients, who are unaccounted for in current CDC statistics, are important because they currently receive diagnostic testing for TBI (head CT scan), and therefore are candidates for testing with novel TBI diagnostics such as circulating biomarkers,[2, 4, 5, 13, 14] neurophysiologic measures,[7] or advanced neuroimaging[15, 16] However the target population for these studies has not been accurately quantified and described. A detailed description ED patients evaluated for TBI is important because it will allow a better understanding of the magnitude of these evaluations and inform the appraisal of studies examining novel TBI diagnostics in the ED to determine their generalizability.

The objectives of this study are: to measure the frequency of ED evaluations for TBI; and to describe the demographic and clinical characteristics and medical care received by ED patients who undergo TBI evaluation.

Methods

We performed a retrospective cross-sectional analysis of ED evaluation of TBI in the United States using data from the National Hospital Ambulatory Medical Care Survey (NHAMCS). The study protocol was reviewed and approved by the institutional review board of the Johns Hopkins University School of Medicine.

NHAMCS is one of the most comprehensive national surveys of ED visits in the United States.[17] It is an annual, national probability-based sample of visits to hospital emergency, and outpatient departments and ambulatory surgery centers.[18] For the hospital component of the survey, visits are sampled from selected non-institutional general and short-stay hospitals located in the 50 states, including the District of Columbia (excluding federal, military, and Veterans Affairs hospitals). Conducted since 1992 by the US Centers for Disease Control and Prevention’s (CDC’s) National Center for Health Statistics, the NHAMCS survey uses a previously described 4-stage probability sampling design to collect data on the use and provision of ambulatory care services.[19] Trained staff from participating hospitals collects data on a systematically selected sample of patient visits during a randomly assigned 4-week period each year. Patient charts are reviewed and relevant data are abstracted using a standardized patient record form. A field representative from the US Bureau of Census reviews the records used for visit sampling to determine if any cases are missing and also reviews completed forms to check for missing data. The data are then processed and coded by an independent company.

To obtain reliable estimates of our outcome measures, we combined data from the 2009 and 2010 surveys to generate robust yearly estimates. The 2010 dataset is the most recent NHAMCS dataset available to the public. The 2009 and 2010 NHAMCS surveys obtained data from 365 and 373 hospitals respectively.[20, 21]

Study population

Our study population was comprised of ED visits in 2009 and 2010 during which TBI was evaluated. Visits during which TBI was evaluated were defined as visits meeting the CDC case definition for TBI[22] or visits for traumatic injuries during which a head CT scan was obtained. The CDC's case definition[22] defines TBI visits as visits with one of the following ICD-9-CM diagnosis codes: fracture of the vault or base of the skull (801.0 – 801.9); other and unqualified multiple fractures of the skull (803.0 – 804.9); intracranial injury including concussion, contusion, laceration and hemorrhage (85 – 854.1); injury to the optic nerve and pathways (951 – 953); shaken baby syndrome (995.55) and head injury unspecified (959.01).[1, 8]

Visits for traumatic injuries were defined as visits with one of the following ICD-9 external-causes-of-injury codes: motor vehicle traffic-related (E810 – E819); other vehicular accidents (E820 – E848); falls (E880 – E888); assault (E960 – E969, E922) and struck by or against an object/person (E916 and E917) similar to classifications by prior CDC reports, [1, 9, 23] or sports-related injury visits (defined as visits for which the cause of injury recorded in the medical chart and abstracted by trained abstractors included one of the following words indicating a contact or limited-contact sport[24]: basketball, football, soccer, bowling, golf, softball, hockey, boxing, wrestling, lacrosse, rugby, derby, squash, bowling, rodeo, martial arts, cycling, polo, skiing, skating, tug of war, diving, exercise, athletic, player or playing). NHAMCS collects data regarding whether a head CT scan was performed during each surveyed ED visit.

Variables examined

We estimated the population of ED patients evaluated for TBI and the proportion of TBI patients who had traumatic abnormalities on head CT scan. Traumatic abnormalities on head CT scan was defined as having one of the following ICD-9-CM diagnoses: skull fracture (800.0 – 801.9; 803.0 – 804.9); or a cerebral laceration, cerebral contusion, subdural hemorrhage, subarachnoid hemorrhage, epidural hemorrhage or unspecified intracranial injury (851.0 – 854.1). We investigated differences in demographic and clinical characteristics between TBI patients without a TBI diagnosis and patients diagnosed with TBI. Variables examined include: age (categorized into 11 groups as per prior reports by the

Centers of Disease Control and Prevention[25]); gender; race (classified as Caucasian non-Hispanic, African-American non-Hispanic, Hispanic and Other); insurance (classified as Medicare/Medicaid, private, other insurance or no insurance); percentage of persons below poverty level in patient's zip code (classified as: <5.0%, 5.0–9.9%, 10.0–19.0%, and >20.0%); triage status (based the widely adopted 5-level Emergency Severity Index[26]);[27, 28] arrival by ambulance; alcohol intoxication (defined as having one of the three cause of injury variables coded as 710 [alcohol abuse]); discharge from any hospital within 7 days and >2 ED visits during the preceding year. Using the Glasgow Coma Scale (GCS), we classified TBI severity into mild (GCS of 13 – 15), moderate (GCS 9 – 12) or severe (GCS <9). Furthermore, we derived head Abbreviated Injury Scale (AIS) scores from International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes using the ICD Programs for Injury Categorization (ICDPIC). ICDPIC is a STATA statistical software module that allows inexpensive translation of ICD-9-CM codes into standard injury categories and/or scores.[29] Head AIS scores are ranked on a scale of 1 to 6, representing minor (1), moderate (2), serious (3), severe (4), critical (5) and unsurvivable injuries (6). Using the Barell body region by nature of injury diagnosis matrix,[30] we categorized the associated non-TBI injuries into: other head, face and neck; spine and back; torso; and extremities based on relevant ICD9-C-M codes. We also determined whether other imaging (x-ray, other CT (non-head) scan or MRI) was performed, and whether patient was evaluated by a resident or midlevel provider. Finally, we examined the emergency department length of stay and disposition status (hospital admission or discharge).

Statistical analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Since numbers and proportions reported are national estimates based on systematic sampling of a fraction of ED visits, all estimates are reported with their corresponding 95% confidence interval (CI). Observed differences between 2 proportions were testing using the χ^2 test. To identify patient characteristics that are associated with being evaluated for but not diagnosed with TBI, we constructed a multi-variable logistic regression model, adjusting for age, gender, race, insurance status, poverty level in patient's zip code, triage acuity level and mode of transportation. A two-tailed p-value of <0.05 was considered statistically significant. Statistical analyses were performed using STATA/MP statistical software version 11.2 (StataCorp, College Station, Texas). To account for the survey sampling design, we used the SVY set of commands from Stata. These commands allow the fitting of statistical models for complex survey data. Using these commands, each sampled patient visit was weighted using pre-assigned survey weights to produce unbiased national estimates.

Results

Demographic and clinical characteristics of ED evaluations for TBI

A total of 69,878 ED visits were surveyed by NHAMCS in 2009 and 2010 representing an estimated 133 million (95% confidence interval (CI): 119 – 146 million) visits made to US EDs each year. TBI was evaluated during 2507 visits, representing an estimated 4.8 million

(95% CI: 4.2 – 5.4 million) visits per year and TBI was diagnosed in 1272 visits, representing an estimated 2.5 million (95% CI: 2.1 – 2.8 million) visits per year. Persons evaluated for TBI were predominantly adults (20 years or older), male and Caucasian. However, children less than 5 years old constituted the largest subset of patients diagnosed with TBI. Compared to patients diagnosed with TBI, patients who were evaluated for TBI but were not ultimately diagnosed with TBI were more likely to be female, have Medicare/ Medicaid, triaged as urgent or emergent, arrive to the ED by ambulance or have had >2 ED visits during the preceding year. The demographics of patients evaluated for TBI and patients diagnosed with TBI are presented in Table 1. After adjusting for age, gender, race, insurance, poverty level in patient’s zip code, triage acuity level and mode of transportation, patients evaluated for TBI but not diagnosed with TBI were more likely to be older (odds ratio (OR): 1.02 [95% confidence interval (CI): 1:01 – 1.03]); uninsured (OR: 1.49 [95% CI: 1.02 – 2.20]) or have non-Medicare/Medicaid/Private insurance (OR: 1.76 [95% CI: 1.02 – 3.03]); or arrive to the ED by ambulance (OR: 1.43 [95% CI: 1.13 – 1.80]).

Falls and motor vehicle collisions were the most common injury mechanism for patients evaluated for TBI. Yearly estimates of the contributions of different injury mechanisms to ED presentations for TBI are presented in Table 2. Sports-related injuries contributed to an estimated 135,273 (95% CI: 96,948 – 173,598) visits. Falls occurred most commonly in persons who were either less than 5 years old or 75 years and older. MVCs and assaults most commonly occurred in persons who were between 15 and 54 years. Sports-related injuries occurred most commonly in persons who were younger than 20 years. Assaults were least likely to occur among persons living in zip codes where <5% of the population lived below poverty, however this group was most vulnerable to sports-related injuries. Alcohol intoxication was most likely to occur in assault related injuries. Table 3 provides detailed data on the demographic and clinical characteristics associated with the different mechanisms of injury.

Nearly half of patients evaluated for TBI were taken to the ED by ambulance, 76% were triaged as either urgent or semi-urgent. Less than 10% of patients were repeat visitors (i.e. discharged from a hospital within the preceding 7 days or had more than 2 ED visits during the preceding year) (see Table 1).

A total of 76.0% of patients in the study population had either a GCS documentation or ICD9-C-M values that permitted calculating Head AIS scores (Head AIS scores could not be calculated in subjects with ICD9-C-M codes that were missing 4^{th} and/or 5^{th} digit). Using data from patients with ICD9-C-M codes permitting the calculation of Head AIS scores, the national estimates of the proportion of patients with minor (1), moderate (2), serious (3), severe (4), critical (5) and unsurvivable injuries (6) are: 9.0%, 85.0%, 2.5%, 3.2%, 0.3% and 0% had Head AIS scores of respectively. Using data from patients who had GCS recorded, that national estimates of the proportion of subjects with mild, moderate and severe TBI were: 94.5%, 2.1%, and 3.5% respectively. GCS was not documented in 57.2% of patients. Patients without GCS documentation were not different from those with GCS documentation in mean age, gender, race, insurance status and triage level. The fourth and/or fifth digit in ICD9-C-M codes of 43.2% of patients were missing, limiting the ability to calculate Head AIS scores in these patients. Subjects in whom Head AIS scores could not be calculated were more likely to be older, have Medicare insurance, or triaged to a high acuity level than those in whom Head AIS scores could be calculated. However, there were no gender or racial differences between those with and without Head AIS scores. Among subjects with both Head AIS and GCS measures, Head AIS scores and GCS were weakly correlated (Spearman's rank correlation co-efficient = −0.15); however, the proportion of patients classified as mild TBI with either method was similar (94.7% with GCS 13 – 15, and 92.9% with Head AIS of 1 or 2).

ED Evaluation of TBI

Patients evaluated for TBI waited a median of 23 minutes (Interquartile range (IQR): 9 – 52 minutes) to be seen by a clinician. An estimated 82% received head CT scans, representing a yearly estimate of 3.9 million (95% CI: 3.4 – 4.4 million) head CT scans. Among patients evaluated for TBI who received a head CT, 9% (95% CI: 8 – 11%) had CT evidence of traumatic abnormalities on head CT, representing 3.5 million (95% CI: 3.1 – 4.0 million) negative head CT scans. However among those with a diagnosis of TBI, 22% (95% CI: 19 – 26%) had CT evidence of traumatic abnormalities on head CT. Among those with abnormal head CT scans, were 53.6% were admitted or observed in the same hospital, or transferred to another hospital. Among those with an abnormal head CT who were admitted to inpatient or observation status, 7.7% were admitted to observation status; 41.0% to a critical care unit; 10.3% to the operating room; 3.1% to a step-down unit and 37.9% to other hospital beds.

At least one other CT scan (non-head) was performed in 27% of patients evaluated for TBI (Table 3). Compared to patients diagnosed with TBI, patients evaluated for TBI but who were not diagnosed with TBI were more likely to receive CT scan of another body-part (non-head) (odds ratio: 2.2 (95% CI: 1.7 – 2.7)). Additional imaging performed in patients evaluated for TBI includes: x-rays (44%) and MRIs (1%), see Table 3. Among patients evaluated for TBI, 31% were diagnosed with other head/face/neck injuries; 10% were diagnosed with spine and back injuries; 7% were diagnosed with torso injuries; and 14% were diagnosed with extremity injuries. Patients evaluated for but not diagnosed with TBI were more likely to be diagnosed with other injuries (Table 4). ED evaluation for TBI lasted a median of 175 minutes (IQR: 117 – 256 minutes). Approximately 85% of patients evaluated for TBI were discharged home from the ED, however, only 68% of patients diagnosed with TBI were referred to a physician or clinic for follow-up (Table 4).

Discussion

The emergency department is the primary gateway to the medical system for acute TBI patients; however, ED evaluations for TBI have not been sufficiently described. This national study fills an important void by reporting a number of important findings. The first is that although the number of ED patients diagnosed with TBI is about 2.5 million (as reported by recent CDC estimates)[8], the total number of ED patients evaluated for TBI is about twice that number, representing 3.6% of all ED visits. This finding suggests that the burden of ED evaluations for TBI is substantial and therefore the need for novel diagnostics to optimize the accuracy, efficiency and cost-effectiveness of these evaluations constitutes an important public health concern deserving further attention. Another important consideration is that both the standard clinical interview and CT scanning[16] have limited sensitivity for diagnosing TBI. Bazarian et al.[31] found that trained research assistants administering a structured clinical interview based on the American Congress of Rehabilitation Medicine's (ACRM) definition of TBI[32] to patients or available witnesses identified over twice as many TBIs as were diagnosed with TBI at ED discharge. Yuh et al. reported that 27% of mild traumatic brain injury (mTBI) patients with normal head CTs had trauma-related abnormalities on MRI.[16] Thus, it is likely that a significant fraction of patients evaluated in the ED for TBI but not ultimately diagnosed did in fact sustain traumatic brain injury. Although imperfect (can miss patients evaluated for TBI without a head CT), our approach of using a combination of TBI ICD-9 codes and head CT imaging in patients presenting with injury-related complaints represents a more robust approach to identifying and quantifying the population of ED patients evaluated for TBI.

Secondly, we have determined that of the approximately 3.9 million head CT scans are obtained in EDs each year to evaluate for TBI 91% did not reveal a traumatic intracranial abnormality. The number of negative head CT scans represents high volume, high cost, but low value testing—not to mention increasingly recognized radiation risk.[33] According to a 2012 report from the Institute of Medicine an estimated $210 billion/year of unnecessary services constitute excessive healthcare costs that yield no benefits to patients.[34] Overuse of head CT scans contributes to this problem.[35]

A number of different approaches, including clinical decision rules,[36–38] circulating biomarkers[2, 4, 13, 39, 40] and quantitative brain electrical activity[7] have been proposed as strategies identifying patients evaluated for TBI who are at high risk of having traumatic abnormalities on their head CT scan. Among existing clinical decision rules, the Canadian head CT rule holds the most promise for reducing avoidable head CTs in TBI evaluation.[41] It recommends obtaining a head CT only in patients with any one of the following symptoms: GCS<15 at 2 hours after injury, suspected open or depressed skull fracture, signs of basal skull fracture, 2 or more episodes of vomiting, 65 years or older, retrograde amnesia to the event or a dangerous mechanism (pedestrian struck, ejection from motor vehicle, fall from >3 feet or 5 stairs). Adherence to this rule is expected to result in a 20–35% reduction of avoidable CTs.[41, 42] However, a randomized control trial that implemented the Canadian head CT rule did not find a resultant reduction in head CT utilization, due to suboptimal adherence to the rule.[43]

Circulating biomarkers have been proposed as screening tools for identifying patients who will benefit the most from CT scans. The Scandinavian guidelines for managing TBI recommend avoiding a head CT scan in low-risk mild TBI patients with S100 calcium-binding protein B (S100B) levels <0.10 μg/L within 6 hours of injury.[44] S100B, a protein predominantly expressed by astrocytes, is released into circulation after damage to the blood brain barrier.[6] Adoption of this strategy in the U.S. has been limited because it is noted that S100B is elevated in patients with fractures and other extra-cranial injuries.[13, 45] Additionally, S100B values are decreased at >6 hours after injury.[5, 36] Glial fibrillary acidic protein (GFAP), an intermediate filament protein expressed predominantly by glial cells[6] has excellent specificity for traumatic abnormalities on head CT on head CT, however, its negative predictive value which ranges between 80–97%[4, 39] (depending on the chosen cutoff and study population) limits its adoption as a screening tool for triaging need for head CT. Further studies are needed to determine the optimal strategy that will result in a reduction in avoidable head CT scans during ED evaluation of TBI.

Thirdly, the majority of patients evaluated for TBI in the ED can be classified as mild TBI. This finding is independent of whether Head AIS or GCS is used for classifying mild TBI. Although the correlation between head AIS and GCS scores was weak, the proportion of patients that could be classified as mild TBI using either method was similar. Demetriades et al similarly found a weak correlation of -0.35 between head AIS and GCS, however, both measures are strongly associated with TBI outcome.[46]

Finally, we have reported the demographic and clinical characteristics of ED patients evaluated for TBI. Although patients evaluated for TBI and those diagnosed with TBI are similar in race and socio-economic status, those evaluated for TBI are more likely to be older and female. However these findings cannot be extrapolated to infer that any particular subgroup of patients may benefit from a head CT or otherwise. Furthermore, as previously discussed, the percentage of head CT scans with traumatic abnormality is 9%. A number of studies investigating ED diagnostic testing of TBI have enrolled populations with a 7–10% prevalence of positive head CTs.[13, 37] Whereas other studies have enrolled populations with a 30–40% prevalence of positive head CTs.[2, 4] For diagnostic studies examining strategies for decreasing head CT utilization in TBI evaluation, using a study population whose prevalence of positive head CT is much higher than our national estimate (9%) will result in higher than expected positive predictive value and a lower than expected negative predictive value.[47] Therefore, our findings of the characteristics of ED patients evaluated for TBI can be useful for judging the generalizability of studies examining novel TBI diagnostics in the ED setting.

Limitations

We have used the NHAMCS survey which is based on probabilistic sampling of ED visits to generate national estimates of the burden and evaluation of TBI in EDs from the sampling of 2505 ED visits. It is possible though unlikely that our estimates may not be a true reflection of the entire population. To ensure the accuracy of our estimates, we have analyzed study data as recommended by NHAMCS,[48, 49] we have also combined data from 2009 and 2010 to generate greater reliability of estimates, finally, we have reported the corresponding 95% confidence intervals of all point estimates. Additionally, since we used ICD9 diagnosis to identify those who were diagnosed with TBI, it is likely that we have underestimated the true burden of TBI diagnosis.

Conclusions

Nearly 5 million ED patients are evaluated for TBI in U.S. EDs each year. Although 82% of these patients receive head CT scans, 91% of the head CT scans have no traumatic abnormalities on head CT. Findings highlight the need for novel tools for diagnosing TBI, without relying on head CT scans. Furthermore, our data provides objective national estimates for determining the generalizability of studies evaluating novel TBI diagnostics in EDs.

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Table 1

Demographics and clinical characteristics of study population

	% All suspected TBI patients (95% CI) n=4.8 million	% Patients diagnosed with TBI (95% CI) n=2.5 million	% evaluated for TBI but not diagnosed with TBI (95% CI) n=2.3 million	p Value*
Age in years				<0.001
• Less than 5	12 (10 – 14)	20 (17 – 23)	3 (2 – 5)	
• 5 – 9	5 (4 – 7)	8 (6 – 10)	3 (2 – 4)	
• 10 – 14	6 (4 – 7)	7 (5 – 10)	4 (2 – 6)	
• 15 – 19	9 (8 – 11)	10 (8 – 12)	8 (6 – 11)	
• 20 – 24	9 (7 – 10)	9 (7 – 11)	8 (6 – 11)	
• 25 – 34	10 (9 – 12)	9 (7 – 11)	11 (9 – 14)	
• 35 – 44	9 (7 – 10)	8 (6 – 10)	9 (7 – 11)	
• 45 – 54	8 (7 – 10)	7 (6 – 9)	10 (8 – 12)	
• 55 – 64	9 (7 – 10)	6 (4 – 8)	12 (10 – 14)	
• 65 – 74	• 7 (6 – 9)	5 (4 – 7)	9 (8 – 12)	
• 75 and older	16 (14 – 18)	11 (9 – 13)	22 (19 – 26)	
Gender				0.014
• Female	45 (43 – 47)	42 (39 – 45)	48 (44 – 51)	
• Male	55 (53 – 57)	58 (55 – 61)	52 (49 – 56)	
Race				0.437
• Caucasian, non- Hispanic	68 (64 – 72)	67 (62 – 71)	69 (64 – 74)	
• African-American, non-Hispanic	16 (13 – 19)	16 (13 – 20)	16 (13 – 20)	
• Hispanic	13 (10 – 16)	13 (10 – 17)	12 (9 – 16)	
• Other	4 (2 – 5)	4 (3 – 7)	3 (2 – 4)	
Insurance				
• Medicare/Medicaid	43 (40 – 46)	39 (35 – 42)	47 (44 – 51)	<0.001
• Private	35 (32 – 38)	41 (37 – 45)	28 (25 – 32)	
• Other Insurance	6 (5 – 8)	6 (4 – 9)	7 (5 – 10)	
• No insurance	16 (14 – 18)	15 (12 – 17)	18 (15 – 22)	
% below poverty in patient's zip code				0.543
• <5%	18 (15 – 21)	18 (15 – 21)	18 (15 – 23)	
• 5.0 – 9.9%	27 (24 – 31)	29 (25 – 33)	26 (21 – 30)	
• 10.0 – 19.9%	31 (27 – 35)	30 (26 – 34)	32 (27 – 38)	
• ≥20%	18 (15 – 21)	17 (14 – 21)	18 (15 – 22)	
Triage status				0.003
• Immediate	3 (2 – 5)	3 (2 – 5)	3 (2 – 5)	
• Emergent	14 (12 – 17)	12 (10 – 15)	16 (13 – 20)	
• Urgent	45 (41 – 48)	42 (38 – 46)	47 (43 – 52)	
• Semi-urgent	31 (28 – 34)	36 (32 – 40)	26 (22 – 30)	
• Non-urgent	3 (2 – 5)	3 (2 – 5)	3 (2 – 6)	
• No triage	4 (2 – 6)	3 (2 – 6)	4 (2 – 7)	

	% All suspected TBI patients (95% CI) n=4.8 million	% Patients diagnosed with TBI (95% CI) n=2.5 million	% evaluated for TBI but not diagnosed with TBI (95% CI) n=2.3 million	p Value*
Arrived by ambulance	42 (39 – 45)	32 (29 – 37)	52 (49 – 55)	<0.001
Alcohol intoxication	6 (5 – 7)	5 (4 – 7)	7 (5 – 8)	0.204
Discharge from any hospital within 7 days	3 (2 – 4)	2 (1 – 4)	3 (2 – 5)	0.378
>2 ED visits with past year	7 (6 – 9)	6 (4 – 7)	9 (7 – 11)	0.012

p Value* is for the difference between patients diagnosed with TBI and suspected TBI patients who were not diagnosed with TBI.

Table 2

Mechanisms of injury for ED visits during which suspected TBI was evaluated

Mechanism	Estimated Number in millions (95% CI) n=4.8 million	Estimated Proportion (%) with corresponding 95% CI n=4.8 million
Fall	2.33 (2.03 – 2.63)	49 (46 – 51)
Motor vehicle collision	0.94 (0.78 – 1.09)	20 (18 – 22)
Struck by/against	0.51 (0.41 – 0.61)	11 (9 – 12)
Assault	0.39 (0.30 – 0.48)	8 (7 – 10)
Other vehicular injury	0.16 (0.12 – 0.21)	3 (3 – 5)
Sports	0.14 (0.09 – 0.19)	3 (2 – 4)
Other injury	0.31 (0.22 – 0.40)	6 (5 – 8)

Table 3

Demographic and clinical characteristics of patients evaluated for TBI according to mechanism of injury

	Fall	MVC	Other Vehicle	Struck by/against	Assault	Sports	Other injury	p- Value
Age categories								<0.001
• Less than 5	17.1	3.5	6.4	17.6	1.1	12.0	5.2	
• 5 – 9	4.5	3.5	11.8	13.8	0.5	11.7	3.0	
• 10 – 14	2.7	3.5	14.9	10.5	6.1	28.2	11.5	
• 15 – 19	3.4	13.7	14.2	15.8	15.7	24.1	10.8	
• 20 – 24	2.5	18.6	6.5	5.4	22.8	8.0	12.5	
• 25 – 34	4.8	15.3	7.4	9.6	25.6	7.1	18.0	
• 35 – 44	5.2	13.9	13.0	10.3	11.5	4.4	12.1	
• 45 – 54	7.9	11.7	3.2	5.0	9.8	4.1	11.7	
• 55 – 64	10.5	8.7	15.9	5.2	5.3	0.0	5.0	
• 65 – 74	11.7	3.5	2.9	3.9	0.1	0.0	4.6	
• 75 and older	29.7	4.1	3.8	2.8	1.4	0.5	5.6	
Race								<0.001
• Caucasian, non- Hispanic	72.9	61.3	71.1	61.5	58.1	82.7	63.7	
• African-American, non-Hispanic	12.3	22.9	11.0	17.7	18.2	7.3	23.1	
• Hispanic	11.9	12.1	17.4	15.9	18.9	7.0	5.7	
• Other	2.9	3.8	0.5	4.9	4.7	3.0	7.5	
Insurance								<0.001
• Medicare/Medicaid	56.9	26.4	28.6	32.9	29.3	22.6	35.7	
• Private	31.1	38.9	48.6	42.7	25.9	63.9	24.9	
• Other Insurance	3.0	11.3	11.3	8.1	7.6	3.4	10.9	
• No insurance	9.0	23.4	11.5	16.4	37.3	10.0	28.5	
% below poverty in patient's zip code								<0.001
• <5%	21.4	17.0	17.4	17.7	8.5	36.9	19.4	
• 5.0 – 9.9%	30.2	27.4	34.1	34.1	23.7	30.1	17.3	
• 10.0 – 19.9%	33.0	32.7	26.7	25.0	43.7	31.3	40.6	
• ≥20%	15.4	22.9	21.8	23.3	24.1	1.7	22.7	
Triage status								<0.001

	Fall	MVC	Other Vehicle	Struck by/against	Assault	Sports	Other injury	p- Value
• Immediate	2.9	5.6	4.7	0.3	2.6	0.8	6.1	
• Emergent	14.9	16.5	27.6	9.8	10.7	3.0	12.1	
• Urgent	48.4	41.4	43.2	38.5	41.2	33.8	45.1	
• Semi-urgent	26.8	28.7	17.9	44.9	38.3	56.4	29.8	
• Non-urgent	3.2	4.4	2.3	2.3	5.3	1.7	3.3	
• No triage	3.8	3.3	4.3	4.2	1.9	4.3	3.6	
Arrived by ambulance	44.8	64.7	44.4	12.2	34.5	16.6	41.7	<0.001
Alcohol intoxication	5.9	3.8	8.1	0.3	12.0	0.0	18.1	<0.001
Discharge from any hospital within 7 days	3.0	3.9	1.6	0.4	1.0	0.8	6.4	0.131
>2 ED visits with past year	7.9	5.5	0.7	6.1	12.2	2.1	9.6	0.033
Traumatic abnormality on head CT	8.4	5.7	20.0	9.1	9.0	11.4	19.4	0.006

Table 4

Diagnostic Evaluation of Suspected TBI in Emergency Departments

	% All suspected TBI patients (95% CI) n = 4.8 million	**% Patients diagnosed with TBI (95% CI) n = 2.5 million**	**% evaluated for TBI but not diagnosed with TBI (95% CI) n = 2.3 million**	**p Value***
X-ray obtained	44 (41 – 47)	33 (29 – 37)	56 (52 – 60)	<0.001
Non-head CT scan obtained	27 (24 – 30)	20 (17 – 23)	35 (31 – 39)	<0.001
MRI obtained	1 (1 – 2)	1 (0 – 2)	1 (1 – 2)	0.350
Seen by a resident	13 (10 – 17)	12 (9 – 17)	14 (11 – 19)	0.280
Seen by a midlevel provider	18 (15 – 21)	20 (16 – 24)	16 (13 – 20)	0.139
Disposition				
• Admission to observation unit	1 (1 – 2)	1 (1 – 2)	1 (1 – 3)	0.691
• Admission to hospital	17 (15 – 19)	13 (10 – 16)	20 (18 – 24)	<0.001
Referral to a physician or clinic for follow-up	66 (62 – 69)	68 (63 – 72)	64 (60 – 68)	<0.134
Traumatic abnormality on head CT	9 (8 – 11)	22 (19 – 26)	NA	NA
Associated non-TBI injuries				
• Other head/face/neck	31 (28 – 33)	23 (20 – 27)	39 (35 – 43)	<0.001
• Spine and back	10 (8 – 11)	9 (7 – 11)	11 (9 – 14)	0.074
• Torso	7 (6 – 8)	4 (3 – 6)	9 (8 – 12)	<0.001
• Extremities	14 (12 – 16)	9 (7 – 10)	20 (17 – 22)	<0.001

p Value* is for the difference between patients diagnosed with TBI and suspected TBI patients who were not diagnosed with TBI. NA = Not applicable