J Head Trauma Rehabil

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

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Objective: To determine the dimensions of traumatic brain injury (TBI) evaluation in US emergency department (EDs) to inform potential application of novel diagnostic tests. **Setting:** US EDs. **Participants:** National Hospital Ambulatory Medical Care Survey of ED visits in 2009 and 2010 where TBI was evaluated (1) and diagnosed either clinically or (2) with head computed tomographic (CT) scans. **Design:** Retrospective cross-sectional. **Results:** TBI was evaluated during 4.8 (95% confidence interval [CI], 4.2-5.4) million visits per year; and head CT scan was performed in 82% of TBI evaluations (3.9 [95% CI, 3.4-4.4] million visits per year). TBI was diagnosed in 52% of evaluations (2.5 [95% CI, 2.1-2.8] million visits per year). Among those who received head CT scans, 9% had CT evidence of traumatic abnormalities. Among patients evaluated for TBI who had a Glasgow Coma Scale score recorded, 94.5% were classified as having mild TBI, 2.1% as moderate TBI, and 3.5% as severe TBI. Among patients with *International Classification of Diseases, Ninth Revision, Clinical Modification*, codes permitting the calculation of head Abbreviated Injury Scale scores 9.0%, 85.0%, 2.5%, 3.2%, 0.3%, and 0% had head Abbreviated Injury Scale scores of 1, 2, 3, 4, 5, and 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. **Conclusion:** The ED is the main gateway to medical care for millions of patients evaluated for TBI each year. Novel diagnostic tests are needed to improve ED diagnosis and management of TBI. **Key words:** *emergency department*, *epidemiology*, *head CT scan*, *imaging*, *traumatic brain injury*

ALTHOUGH TRAUMATIC BRAIN INJURY (TBI) remains an important cause of death and disability in the United States,[1] objective diagnosis and accurate determination of TBI prognosis remain 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 emergency department (ED). However, the target population of these studies (ie, patients evaluated for TBI in EDs) has not been described in sufficient detail.

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Prior studies have described ED patients with a diagnosis of 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 ED visits, hospitalizations, or deaths associated with TBI in 2010.[8] This estimate includes only patients with a diagnosis of TBI and does not account for numerous patients presenting with traumatic injury who were evaluated for TBI with a head computed tomographic (CT) scan but who did not ultimately receive a diagnosis of 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 of 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 were 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 noninstitutional 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 CDC's National Center for Health Statistics, NHAMCS 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 data set is the most recent NHAMCS data set available to the public. The 2009 and 2010 NHAMCS obtained data from 365 and 373 hospitals, respectively.[20,21]

Study population

Our study population comprised 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 *International Classification of Diseases, Ninth Revision* (*ICD-9*), *Clinical Modification* (*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 with a diagnosis of TBI. Variables examined include age (categorized into 11 groups as per prior reports by the CDC[9]); gender; race (as White 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 on the widely adopted 5-level Emergency Severity Index[25]);[26,27] arrival by ambulance; alcohol intoxication (defined as having 1 of the 3 cause of injury variables coded as 710 [alcohol abuse]); discharge from any hospital within 7 days and more than 2 ED visits during the preceding year. Using the Glasgow Coma Scale (GCS), we classified TBI severity into mild (GCS score = 13-15), moderate (GCS score = 9-12), or severe (GCS score <9). Furthermore, we derived head Abbreviated Injury Scale (AIS) scores from *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.[28] 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,[29] we categorized the associated non-TBIs 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 (radiography, other CT [nonhead] scan, or magnetic resonance imaging) was performed and whether patient was evaluated by a resident or midlevel provider. Finally, we examined the ED 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 multivariable 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 2-tailed P value of less than .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 preassigned 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 (95% CI, 119-146) million visits made to US EDs each year. TBI was evaluated during 2507 visits, representing an estimated 4.8 (95% CI, 4.2-5.4) million visits per year and TBI was diagnosed in 1272 visits, representing an estimated 2.5 (95% CI, 2.1-2.8) million visits per year. Persons evaluated for TBI were predominantly adults (20 years or older), male, and White. However, children younger than 5 years constituted the largest subset of patients with a diagnosis of TBI. Compared with patients with a diagnosis of TBI, patients who were evaluated for TBI but did not ultimately receive a diagnosis of TBI were more likely to be female, have Medicare/Medicaid insurance, triaged as urgent or emergent, arrive to the ED by ambulance, or have had more than 2 ED visits during the preceding year. The demographics of patients evaluated for TBI and patients with a diagnosis of 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 did not receive a diagnosis of TBI were more likely to be older (odds ratio [OR] = 1.02 [95% 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 either were younger than 5 years or were 75 years and older. Motor vehicle collisions and assaults most commonly occurred in persons who were between 15 and 54 years of age. 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 less than 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 semiurgent. Less than 10% of patients were repeat visitors (ie, 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 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 fourth and/or fifth digits). 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 as follows: 9.0%, 85.0%, 2.5%, 3.2%, 0.3%, and 0%, respectively, had head AIS scores. Using data from patients who had GCS scores recorded, the national estimates of the proportion of subjects with mild,

TABLE 1 *Demographics and clinical characteristics of the study population*

	% All suspected TBI patients (95% CI) (*N* = 4.8 million)	% Patients with a diagnosis of TBI (95% CI) (*n* = 2.5 million)	% Evaluated for TBI but did not receive a diagnosis of TBI (95% CI) (*n* = 2.3 million)	*P*[a]
Age, y				<.001
<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	16 (14-18)	11 (9-13)	22 (19-26)	
Gender				.014
Female	45 (43-47)	42 (39-45)	48 (44-51)	
Male	55 (53-57)	58 (55-61)	52 (49-56)	
Race				.437
White, 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)	<.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				.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				.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)	
Semiurgent	31 (28-34)	36 (32-40)	26 (22-30)	
Nonurgent	3 (2-5)	3 (2-5)	3 (2-6)	
No triage	4 (2-6)	3 (2-6)	4 (2-7)	
Arrived by ambulance	42 (39-45)	32 (29-37)	52 (49-55)	<.001
Alcohol intoxication	6 (5-7)	5 (4-7)	7 (5-8)	.204
Discharge from any hospital within 7 d	3 (2-4)	2 (1-4)	3 (2-5)	.378
>2 emergency department visits within past year	7 (6-9)	6 (4-7)	9 (7-11)	.012

Abbreviations: CI, confidence interval; TBI, traumatic brain injury.
[a] *P* value is for the difference between patients with a diagnosis of TBI and suspected TBI patients who did not receive a diagnosis of TBI.

moderate, and severe TBI were 94.5%, 2.1%, and 3.5%, respectively. The GCS score 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 digits 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

TABLE 2 *Mechanisms of injury for emergency department visits during which suspected traumatic brain injury 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)

Abbreviation: CI, confidence interval.

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 and GCS scores were weakly correlated (Spearman rank correlation coefficient = −0.15); however, the proportion of patients classified as having mild TBI with either method was similar (94.7% with GCS scores of 13-15, and 92.9% with head AIS score of 1 or 2).

ED evaluation of TBI

Patients evaluated for TBI waited a median of 23 (interquartile range = 9-52) minutes to be seen by a clinician. An estimated 82% received head CT scans, representing a yearly estimate of 3.9 (95% CI, 3.4-4.4) million head CT scans. Among patients evaluated for TBI, 9% (95% CI, 8-11) had CT evidence of traumatic abnormalities on head CT scans, representing 3.5 (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 scans. Among those with abnormal head CT scans, 53.6% were admitted or observed in the same hospital or transferred to another hospital. Among those with an abnormal head CT scans 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 (nonhead) was performed in 27% of patients evaluated for TBI (see Table 3). Compared with patients with a diagnosis of TBI, patients evaluated for TBI but who did not receive a diagnosis of TBI were more likely to receive a CT scan of another body part (nonhead) (OR = 2.2 [95% CI, 1.7-2.7]). Additional imaging performed in patients evaluated for TBI includes radiography (44%) and magnetic resonance imaging (1%) (see Table 3). Among patients evaluated for TBI, 31% received a diagnosis of other head/face/neck injuries; 10% received a diagnosis of spine and back injuries; 7% received a diagnosis of torso injuries; and 14% received a diagnosis of extremity injuries. Patients evaluated for but did not receive a diagnosis of TBI were more likely to receive a diagnosis of other injuries (see Table 4). ED evaluation for TBI lasted a median of 175 (interquartile range = 117-256) minutes. Approximately 85% of patients evaluated for TBI were discharged home from the ED; however, only 68% of patients who received a diagnosis of TBI were referred to a physician or clinic for follow-up (see Table 4).

DISCUSSION

The ED is the primary gateway to the medical system for patients with acute TBI; 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 who received a diagnosis of 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 scans[16] have limited sensitivity for diagnosing TBI. Bazarian et al[30] found that trained research assistants administering a structured clinical interview based on the American Congress of Rehabilitation Medicine's definition of TBI[31] to patients or available witnesses identified more than twice as many TBIs as were diagnosed with TBI at ED discharge. Yuh et al[16] reported that 27% of mild TBI patients with normal head CT scans had trauma-related abnormalities on magnetic resonance images. Thus, it is likely that a significant fraction of patients evaluated in the ED for TBI but did not ultimately receive a diagnosis did in fact sustain TBI. Although imperfect (can miss patients evaluated for TBI without a head CT scan), our approach of using a combination of TBI *ICD-9* codes and head CT scans in patients presenting with injury-related complaints represents a more robust

TABLE 3 *Demographic and clinical characteristics of patients evaluated for traumatic brain injury according to the mechanism of injury*

	Fall	Motor vehicle collision	Other vehicular injury	Struck by/ against	Assault	Sports	Other injury	*P*
Age categories, y								<.001
<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	29.7	4.1	3.8	2.8	1.4	0.5	5.6	
Race								<.001
White, 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								<.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								<.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								<.001
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	
Semiurgent	26.8	28.7	17.9	44.9	38.3	56.4	29.8	
Nonurgent	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	<.001
Alcohol intoxication	5.9	3.8	8.1	0.3	12.0	0.0	18.1	<.001
Discharge from any hospital within 7 d	3.0	3.9	1.6	0.4	1.0	0.8	6.4	.131
>2 emergency department visits within past year	7.9	5.5	0.7	6.1	12.2	2.1	9.6	.033
Traumatic abnormality on head computed tomographic scan	8.4	5.7	20.0	9.1	9.0	11.4	19.4	.006

approach to identifying and quantifying the population of ED patients evaluated for TBI.

Second, we have determined that of the approximately 3.9 million head CT scans obtained in EDs each year to evaluate 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.[32] According to a 2012 report from the Institute of Medicine, an estimated $210 billion per year of unnecessary services constitute excessive healthcare costs that yield no benefits to patients.[33] Overuse of head CT scans contributes to this problem.[34]

TABLE 4 *Diagnostic evaluation of suspected TBI in emergency departments*

	% All suspected TBI patients (95% CI) (N = 4.8 million)	% Patients with a diagnosis of TBI (95% CI) (n = 2.5 million)	% Evaluated for TBI but did not receive a diagnosis of TBI (95% CI) (n = 2.3 million)	P[a]
Radiographs obtained	44 (41-47)	33 (29-37)	56 (52-60)	<.001
Nonhead CT scans obtained	27 (24-30)	20 (17-23)	35 (31-39)	<.001
Magnetic resonance images obtained	1 (1-2)	1 (0-2)	1 (1-2)	.350
Seen by a resident	13 (10-17)	12 (9-17)	14 (11-19)	.280
Seen by a midlevel provider	18 (15-21)	20 (16-24)	16 (13-20)	.139
Disposition				
Admission to the observation unit	1 (1-2)	1 (1-2)	1 (1-3)	.691
Admission to hospital	17 (15-19)	13 (10-16)	20 (18-24)	<.001
Referral to a physician or clinic for follow-up	66 (62-69)	68 (63-72)	64 (60-68)	<.134
Traumatic abnormality on head CT–associated non-TBIs	9 (8-11)	22 (19-26)	NA	NA
Other head/face/neck	31 (28-33)	23 (20-27)	39 (35-43)	<.001
Spine and back	10 (8-11)	9 (7-11)	11 (9-14)	.074
Torso	7 (6-8)	4 (3-6)	9 (8-12)	<.001
Extremities	14 (12-16)	9 (7-10)	20 (17-22)	<.001

Abbreviations: CI, confidence interval; CT, computed tomographic; NA, not applicable; TBI, traumatic brain injury.
[a] P value is for the difference between patients with a diagnosis of TBI and suspected TBI patients who did not receive a diagnosis of TBI.

A number of different approaches, including clinical decision rules,[35–37] circulating biomarkers,[2,4,13,38,39] 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 scans. Among existing clinical decision rules, the Canadian Head CT Rule holds the most promise for reducing avoidable head CT scans in TBI evaluation.[40] It recommends obtaining a head CT only in patients with any one of the following symptoms: GCS score less than 15 at 2 hours after injury, suspected open or depressed skull fracture, signs of basal skull fracture, 2 or more episodes of vomiting, aged 65 years or older, retrograde amnesia to the event, or a dangerous mechanism (pedestrian struck, ejection from motor vehicle, fall from >3 ft or 5 stairs). Adherence to this rule is expected to result in a 20% to 35% reduction in avoidable CT scans.[40,41] 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.[42]

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 less than 0.10 μg/L within 6 hours of injury.[43] 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 United States has been limited because it is noted that S100B is elevated in patients with fractures and other extracranial injuries.[13,44] In addition, S100B values decrease at more than 6 hours after injury.[5,35] Glial fibrillary acidic protein, an intermediate filament protein expressed predominantly by glial cells,[6] has excellent specificity for traumatic abnormalities on head CT scans; however, its negative predictive value, which ranges between 80% and 97%,[4,38] (depending on the chosen cutoff and study population), limits its adoption as a screening tool for triaging need for head CT scans. 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.

Third, the majority of patients evaluated for TBI in the ED can be classified as having mild TBI. This finding is independent of whether head AIS or GCS score is used for classifying mild TBI. Although the correlation between head AIS and GCS scores was weak, the proportion of patients who could be classified as having mild TBI using either method was similar. Demetriades et al[45] similarly found a weak correlation of −0.35

between head AIS and GCS scores; however, both measures are strongly associated with TBI outcome.

Finally, we have reported the demographic and clinical characteristics of ED patients evaluated for TBI. Although patients evaluated for TBI and those who receive a diagnosis of TBI are similar in race and socioeconomic 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 scan 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% to 10% prevalence of positive head CT scans,[13,36] whereas other studies have enrolled populations with a 30% to 40% prevalence of positive head CT scans.[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 scans 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.[46] 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 NHAMCS, 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 although 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.[47,48] We have also combined data from 2009 and 2010 to generate greater reliability of estimates. Finally, we have reported the corresponding 95% CIs of all point estimates. In addition, since we used *ICD-9* diagnosis codes to identify those who received a diagnosis of TBI, it is likely that we have underestimated the true burden of TBI diagnosis.

CONCLUSION

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

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