Brain Injury, February 2005; 19(2): 85–91

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Mild traumatic brain injury in the United States, 1998–2000

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Abstract

Primary objective: To determine the incidence and epidemiology of emergency department (ED)-attended mild traumatic brain injury (mTBI) in the US.

Research design: Secondary analysis of ED visits for mTBI in the National Hospital Ambulatory Medical Care Survey for 1998–2000.

Methods and procedures: MTBI defined by International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes for 'skull fracture', 'concussion', 'intracranial injury of unspecified nature' and 'head injury, unspecified'.

Main outcome and results: The average incidence of mTBI was 503.1/100 000, with peaks among males (590/100 000), American Indians/Alaska Natives (1,026/100 000) and those <5 years of age (1,115.2/100 000). MTBI incidence was highest in the Midwest region (578.4/10 000) and in non-urban areas (530.9/100 000) of the US. Bicycles and sports accounted for 26.4% of mTBI in the 5–14 age group.

Conclusions: The national burden of mTBI is significant and the incidence higher than that reported by others. Possible explanations are discussed. Bicycle and sports-related injuries are an important and highly preventable cause of mTBI underscoring the need to promote prevention programmes on a national level.

Introduction

Over 85% of the 1.5 million traumatic brain injuries (TBIs) that occur in the US annually are considered 'mild'. Despite this designation, mild TBI (mTBI) has been found to be associated with cognitive, physical, psychological and social dysfunction resulting in significant disability and unemployment [1–4]. Post-concussive symptoms affect up to 50% of mTBI patients at 1 month and 15–25% at 1 year [5–7]. The magnitude of this injury and its sequelae prompted the National Institutes of Health to declare in 1999 that mTBI was a major public health problem and that efforts to reduce post-mTBI disability should be a national research priority [8]. Aside from educational management of symptoms, there are no effective treatments. Thus, disability reduction efforts have focused on primary prevention, which depends heavily on knowledge of mTBI epidemiology.

Most patients with mTBI present to the emergency department (ED) for care, yet the incidence and characteristics of such patients are not known. This is a crucial pre-requisite to prevention and disability reduction efforts. Prior studies have estimated the incidence of ED-attended TBI, but not specifically mTBI. Sosin et al. [9] found the incidence of mild and moderate TBI presenting to EDs in 1991 to be 218.3/100 000. Jager et al. [10] reported the incidence of all-severity TBI presenting to EDs between 1992–1994 to be 444/100 000 and Guerrero et al. [11] found the incidence of all-severity TBI discharged from the ED between 1995–1996 to be 392/100 000.

While a clinical definition of mTBI has existed for 10 years (loss of consciousness <10 minutes or amnesia, Glasgow Coma Scale score of 13–15, no skull fracture on physical examination and a nonfocal neurologic exam) [12], the lack of an administrative case definition (i.e. based on ICD-9-CM codes) has made a population-based determination of the incidence of mTBI from pre-existing nationally representative datasets difficult. The recent proposal of

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(Received 7 August 2003; accepted 29 April 2004).

ISSN 0269–9052 print/ISSN 1362–301X online
DOI: 10.1080/02699050410001720158

such a definition by the Centers for Disease Control and Prevention (CDC) now makes this determination possible [13].

The objective of the current study is to determine the incidence and epidemiology of ED-attended mTBI in the US.

Methods

The authors performed a secondary analysis of ED visits in the National Hospital Ambulatory Medical Care Survey (NHAMCS) for the years 1998–2000. Patients meeting the administrative case definition of mTBI during these years were analysed.

NHAMCS is a multi-stage probability sample of ~25 000 ED visits collected each year by the CDC and the National Center for Health Statistics. Hospitals are randomly selected within geographically defined areas (Primary Sampling Units), after adjustment for size, in order to represent the US population [10, 14]. The ED records from selected hospitals are abstracted for data in several categories including patient demographics, physical exam elements, diagnostic tests and procedures, treatments rendered, final ED diagnosis and disposition. The NHAMCS dataset is available to the public through the National Center for Health Statistics web-site [14].

The NHAMCS dataset does not contain information on amnesia or loss of consciousness, which are part of the clinical definition of mTBI. Cases of mTBI were, thus, identified by the following ED billing ICD-9-CM codes found in the primary, secondary or tertiary diagnosis fields: 'skull fracture' (800.0, 800.5, 801.0, 801.5, 803.0, 803.5, 804.0, 804.5), 'concussion' (850.0, 850.1, 850.5, 850.9), 'intracranial injury of unspecified nature' (854.0) and 'head injury, unspecified' (959.0). These codes are intended to identify TBI's that approximate the mTBI clinical definition. They were recommended as the administrative case definition of mTBI for surveillance and research by the Centers for Disease Control and Prevention Mild Traumatic Brain Injury Work Group in October 2002 [13].

Variables related to mTBI epidemiology were analysed. These included age, gender, race, ethnicity, mechanism of injury and location of injury. Race and ethnicity variables originate from ED providers, not from the patient. Mechanisms of injury were grouped (by E-codes) to facilitate analysis. 'Motor vehicle trauma' included railway accidents (E800–E807), motor vehicle traffic accidents (E810–E819), motor vehicle non-traffic accidents (E820–E825) and accidents involving other vehicles not elsewhere classifiable (E848). 'Sports injuries' included falls during sports (E886.0), accidentally being struck during sports (E917.0) and injuries involving horses (E828). 'Injury intent undetermined' included injury undetermined whether accidentally or purposefully inflicted (E980–E989) and legal intervention (E970–E978).

The number and sample frequency of the aforementioned variables among all mTBI patients were determined. Sample frequencies were used to calculate national estimates using the 'patient weight' variable contained in the NHAMCS data set. Annual averages were calculated from the pooled 1998–2000 national estimates. Incidence rates were calculated using mid-1999 population figures from the US Census Bureau included in NHAMCS on-line documentation [15], except for 'ethnicity', which used mid-2000 Census Bureau figures [16]. Confidence intervals and relative standard errors were calculated using SUDAAN software 7.5 (Research Triangle Park, NC) and, in some cases, using the generalized variance estimation equations included in NHAMCS on-line documentation [17]. Statistical significance was defined as $p \leq 0.05$. All other statistical analyses were performed using the Statistical Analysis System (SAS), Version 8.2 (Cary, NC).

Study Exemption under 'Secondary Use of Pre-existing Data' was granted by the Research Subjects Review Board of the University of Rochester.

Results

Of the 70 900 ED visits in the pooled 3-year sample, 878 (1.23%) were for mTBI, representing 4.1 million ED visits (Table I). The mean number of ED visits annually for mTBI was 1 367 101, representing 503.1/100 000 population (Table II).

Table I. ED visits for mild TBI in the National Hospital Ambulatory Medical Care Survey, 1998–2000.

	1998	1999	2000	Total 1998–2000
ED visits in sample	24 175	21 103	25 622	70 900
Estimated ED visits nationally	100 385 193	102 764 669	108 016 777	311 166 639
Mild TBI ED visits in sample	299	269	310	878
Estimated mild TBI ED visits nationally	1 312 304	1 372 373	1 416 625	4 101 302

Table II. ED visits for mild TBI 1998–2000, demographic characteristics.

Characteristic	Mean number per year	95% CI	Annual incidence (per 100k pop.)	95% CI
Overall	1 367 101	(1 210 489; 1 523 713)	503.1	(445.4, 560.7)
Gender				
Male	781 628	(678 399; 884 857)	590.0	(512.1, 667.9)
Female	585 472	(498 881; 672 063)	420.4	(358.2, 482.5)
Age				
<5	218 727	(172 358; 265 097)	1115.2	(878.8, 1351.6)
5–14	297 561	(235 774; 359 349)	733.3	(581.0, 885.5)
15–24	261 319	(196 631; 326 008)	688.7	(518.2, 859.1)
25–34	163 373	(126 472; 200 274)	430.8	(333.5, 528.1)
35–44	158 915	(120 703; 197 127)	356.4	(270.7, 442.1)
45–54	106 665	(74 984; 138 346)	299.7	(210.7, 388.7)
55–64	51 349	(28 851; 73 847)	222.8	(125.2, 320.4)
65–74	38 780	(19 153; 58 407)	217.9	(107.6, 328.2)
>74	70 423	(45 283; 95 563)	480.1	(308.7, 651.5)
Race				
White	1 096 255	(951 907; 1 240 605)	491.0	(426.4, 555.7)
Black/African American	219 329	(169 498; 269 160)	624.6	(482.7, 766.5)
Asian and/or Native Hawaiian/other Pacific Islander	26 108	(6 269; 45 948)	239.6	(57.5, 421.7)
American Indian/ Alaska Native	25 407	(4 918; 45 897)	1026.2	(198.6, 1853.7)
Ethnicity				
Hispanic/Latino	122 009	(84 671; 159 347)	342.3	(237.6, 447.1)
Non-Hispanic/Latino	963 961	(829 305; 1 098 618)	391.1	(336.5, 445.7)
Blank	281 129	(207 615; 354 645)	NA	NA
Region				
Northeast	244 182	(197 429; 290 936)	464.7	(375.8, 553.7)
Midwest	386 515	(283 959; 489 072)	578.4	(424.9, 731.8)
South	428 038	(340 746; 515 331)	443.6	(353.1, 534.0)
West	308 364	(242 110; 374 619)	552.4	(433.7, 671.1)

The highest incidence of mTBI occurred among males, American Indians/Alaska Natives and among those less than 5 years of age. The incidence of mTBI among non-Hispanic/Latinos was greater than among Hispanic/Latinos, but ethnicity data was missing in 20.6% of the cohort (Table II). Mild TBI incidence was highest in the Midwest region of the US and lowest in the South. Areas defined by the CDC as urban ('metropolitan statistical areas') had lower mTBI incidence than non-urban areas (496.0 vs 530.9/100 000).

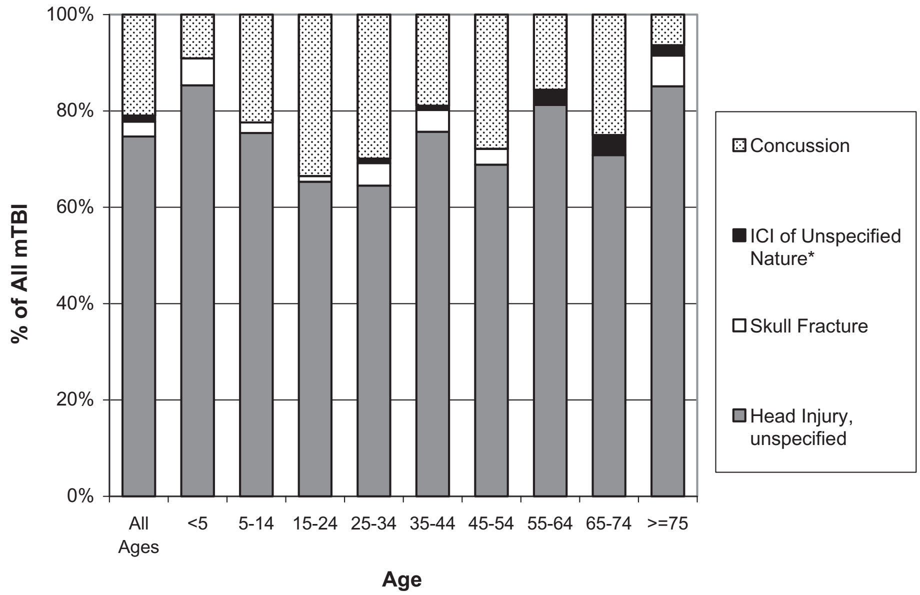
Over 73% of all mTBI cases were associated with the ICD-9-CM codes for 'head injury, unspecified', numbering 356.3/100 000 (Figure 1, first column). The incidence of 'concussion' was 127.8/100 000, of 'skull fracture' 16.4/100 000 and of 'intracranial injury of unspecified nature' 2.6/100 000. The distribution of mTBI ICD-9-CM categories varied by age, with a greater proportion of those <5 and >75 years old receiving codes for 'head injury, unspecified' compared with other groups (Figure 1).

'Falls' and 'motor vehicle trauma' were the most frequent mechanisms of injury (Table III). Mechanism of injury varied considerably by age with 'falls' being frequent at the extremes of age, 'assaults' and 'motor vehicle trauma' in the middle age groups (Figure 2). When combined, 'bicycles' and 'sports' constituted the largest cause of mTBI in the 5–14 age group, accounting for 26.4% of all mTBIs. The most common location of mTBI was 'residence', followed closely by 'street/highway'. Location of injury was not known in 20.68% of the cohort (Table III).

Nine hundred and eighty-two (0.07%) mTBI patients died in the ED (the cause of death is not captured by the NHAMCS) and 135 521 (9.91%) were admitted to the hospital. Most patients had private insurance (45.4%), followed by self-pay (16.6%), Medicaid (12.8%), Medicare (7.8%) and Worker's Compensation (4.9%).

Discussion

In the current study, the authors have estimated the average national annual incidence of ED-attended mTBI between 1998–2000 to be 503.1/100 000. While others have reported the national incidence



*Intracranial injury of unspecified nature

Figure 1. ED visits for mild TBI 1998–2000, distribution of ICD-9-CM categories by age group.

Table III. ED visits for mild TBI 1998–2000, mechanism and location of injury.

Characteristic	Mean number per year	95% CI	Annual incidence (per 100 k pop.)	95% CI
Mechanism				
Fall	405 915	(330 677; 481 154)	149.4	(121.7, 177.1)
MV trauma[a]	313 631	(256 182; 371 081)	115.4	(94.3, 136.6)
Accidentally struck	224 431	(176 899; 271 964)	82.6	(65.1, 100.1)
Assault	170 175	(128 458; 211 892)	62.6	(47.3, 78.0)
Sports	87 509	(57 000; 118 019)	32.3	(21.0, 43.4)
Bicycles	59 668	(35 751; 83 586)	22.0	(13.2, 30.8)
Natural/environmental	34 619	(16 972; 52 266)	12.7	(6.2, 19.2)
Other mechanism	921	(5 577; 26 611)	5.9	(2.1, 9.8)
Location				
Residence	385 278	(272 611; 497 945)	141.8	(117.2, 166.4)
Street/Highway	356 598	(248 701; 464 495)	131.2	(108.5, 153.9)
Unknown	282 655	(187 741; 377 568)	104.0	(83.9, 124.1)
Recreation/sport	96 229	(42 574; 149 884)	35.4	(22.3, 48.5)
School	70 903	(25 051; 116 755)	26.1	(17.5, 34.7)
Other public building	60 863	(18 457; 103 269)	22.4	(12.4, 32.4)
Other location	62 718	(19 656; 105 780)	23.1	(14.3, 31.9)
Industrial place	51 853	(12 774; 90 931)	19.1	(11.2, 27.0)

[a]MV = motor vehicle.

of ED-attended TBI, to the authors' knowledge this is the first report focusing specifically on mTBI.

Prior TBI incidence estimate, which ranged from 218.3–444/100 000 [9–11] and ostensibly included mTBI patients, are significantly lower than these. There are several possible explanations for this.

First, it is possible that the number of Americans presenting to EDs with mTBI has increased since the time of these prior reports. This is not to imply that more Americans are incurring this injury, just that the number presenting to EDs is increasing. While there is no direct evidence to support this line of speculation, it is indirectly supported by the observation that there has been a 14% increase in the number of ED visits for all causes between 1992–1999 [18].

Secondly, previously studied TBI cohorts employed research methodologies that likely resulted in an under-estimation of the true TBI incidence. Guerrero et al.'s [11] study did not include hospitalized TBI patients, effectively eliminating ~10% of all mTBI patients. Sosin et al. [9] analysed the

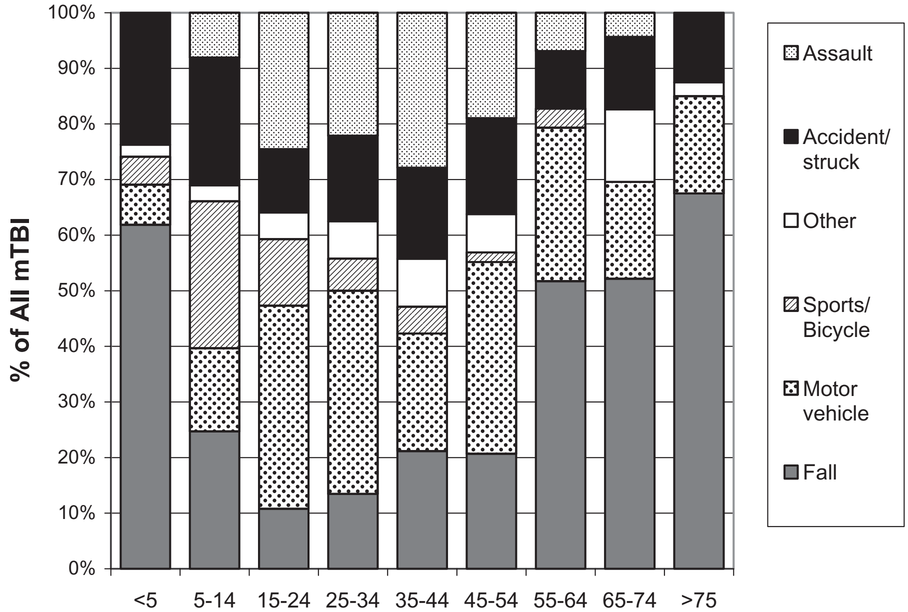


Figure 2. ED visits for mild TBI 1998–2000, distribution of mechanism of injuries by age group.

National Health Interview Survey which, unlike NHAMCS, uses direct patient interview at variable lengths of time after the injury. Inaccurate case ascertainment and recall bias likely resulted in under-reporting of actual cases of mTBI.

Finally, the incidence estimates might differ from others because of the use of ICD-9-CM code 959 'head injury, unspecified' to define mTBI. Previous researchers have defined TBI using the ICD-9-CM codes recommended by the CDC in 1995: 800.0–801.9 (fracture of vault or base of skull), 803.0–804.9 (other unqualified and multiple skull fractures), 850.0–850.9 (concussion) and 851.0–854.1 (intra-cranial injury including contusion, laceration and haemorrhage) [19]. The CDC's recent administrative case definition of mTBI includes codes that are a sub-set of the 1995 TBI codes and excludes 851.0–854.1 all together. Thus, one might expect the incidence estimates of mTBI to be smaller than those for TBI. However, the CDC administrative case definition of mTBI includes a new code, 'head injury, unspecified', which was not a part of the original 1995 CDC definition of TBI (perhaps because 'head injury, unspecified' did not begin appearing in large numbers until 1997, 2 years after the original CDC TBI definition was published). The large number of patients with 'head injury, unspecified' could explain why the incidence estimates are higher than those for TBI and raises an interesting question: What is the relationship between 'head injury, unspecified' and the clinical definition of mTBI?

In a review of 456 ED patients coded as 'head injury, unspecified' at University of Rochester Medical Center, 45% did not meet the clinical definition of mTBI. Most of these were given the ED discharge diagnosis of 'closed head injury' and lacked ED chart documentation of loss of consciousness or amnesia, which would have made them more appropriate for the concussion ICD-9-CM code category. This proportion probably varies from region-to-region, depending on coding practices. The use of 'head injury, unspecified' in the administrative definition of mTBI, thus, likely results in an over-estimation of the incidence of mTBI.

'Head injury, unspecified' may also be responsible for the mTBI incidence spikes observed in the less than 5 and greater than 75 year old age groups. The inability of ED providers to obtain an accurate history of LOC or amnesia in these age groups (either due to non-verbal status or dementia) may result in poor ED chart documentation for these variables which, in turn, forces coders to assign 'head injury, unspecified'. This is a limitation of retrospective method used to generate administrative data. If encountered prospectively, many of these patients would not be classified as mTBI, but would have received an ICD-9-CM code outside of the definition (such as 873, Other Open Would of the Head). Thus, these incidence spikes, especially the less than 5 year old spike, may be artifactual.

Another limitation of the administrative mTBI definition is that it relies on an interpretation of information documented by health care providers in the ED chart. Cases of mTBI that were clinically apparent to the health care providers in the ED setting may be missed by the ICD-9-CM definition because of poor ED chart documentation. Evidence for this was recently found during 3 months of prospective ED-based mTBI surveillance at the University of Rochester Medical Center, where 46.5% of patients who met the clinical definition of mTBI did not receive an ICD-9-CM mTBI designation by ED billing coders. While this proportion, too, likely varies from region-to-region, it is clear that the CDC administrative definition, at the same time, under-estimates the true mTBI incidence. To what extent the over-estimation effect of code 959 is balanced by this under-estimation is not known. Further research in this area is needed. The additional collection of clinical data (such as loss of consciousness) to ICD-9-CM codes could improve the accuracy of the CDC administrative mTBI definition.

Despite these limitations, there are several interesting aspects of the epidemiology of mTBI. First, the mTBI incidence among American Indian/Alaska Natives (AI/ANs) appears to be over twice that of the general American population (1,026 vs 503.1/100 000). A recent report by the CDC revealed the TBI incidence among hospitalized AI/ANs to be less than the general American population (81.7 vs 98/100 000) [20, 21]. The reason for this discrepancy and the high mTBI incidence in this ethnic group is unclear and deserves further study.

Secondly, motor vehicle trauma was the second most frequent cause of mTBI overall, under-scoring the need to reinforce seatbelt use and increase the availability of frontal and side-impact airbags. However, bicycle and sports-related injuries are an important and perhaps under-emphasized cause of mTBI in the 5–14 year old age group. In the current study, the authors found that bicycle and sports-related injuries were the most frequent cause of mTBI in this age group, responsible for 26.9% of all mTBIs. Injuries caused by these mechanisms are highly preventable through the use of helmets, which have been shown to decrease bicycle-related TBI risk by 88% [22]. Efforts to improve access to and use of helmets during cycling and other high-risk sports should continue to be a national priority.

Thirdly, regional differences in mTBI incidence appear to exist. Those presenting to EDs in the Midwest had higher mTBI incidence than those in other regions in the US, while non-urban areas had higher mTBI incidence than urban areas. While these differences could be confounded by other variables related to TBI incidence such as age or race, others have reported similar trends [23]. Understanding the causes for geographic variations in mTBI incidence could provide clues for primary prevention, which is currently the most effective means of overall mTBI disability reduction.

Finally, improvements in ED chart documentation and NHAMCS coding practices could lead to substantial improvements in one's ability to characterize mTBI patients nationally. Location of injury information is crucial for the design of targeted prevention programmes, yet was missing in nearly one fifth of patients. Ethnicity data, a key variable for identifying disparities in ED care, was also missing in one fifth of patients. Glasgow Coma Scale scores, an essential part of TBI severity determination, were not recorded at all by NHAMCS coders. National efforts to improve the recording and collection of these variables would be vital for accurately defining the epidemiology of this injury and for informing programmes designed to prevent mTBI.

Conclusions

Between 1998–2000, the average annual incidence of mTBI in the US was 503.1/100 000, higher than previously published TBI incidence estimates. There are several limitations to the newly released CDC administrative case definition of mTBI which appears to both under- and over-estimate the true mTBI incidence. The mTBI incidence was highest for American Indians/Alaska Natives, those less than 5 years old, those in the Midwest and those living in non-urban areas. The causes for these trends deserve further investigation and could provide clues for future prevention efforts. Although falls and motor vehicle crashes remain the most frequent causes of mTBI, bicycle and sports-related injuries are an important and highly preventable cause of this injury. National efforts to improve access to and use of protective head gear during sports, as well as seatbelts and airbag protection systems while driving, should continue to be a goal of injury prevention programmes.

Acknowledgement

The authors would like to thank Susan Fisher, PhD and Ollivier Hyrien, PhD for their statistical assistance. The authors would also like to thank Peggy Auinger for assistance with SUDAAN programming. Dr Bazarian is supported by a Mentored Patient-Oriented Research Career Development Award from the National Institutes of Neurologic Disorders and Stroke (1K23 NS4195-03).

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