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Head injuries (TBI) to adults and children in motor vehicle crashes

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Abstract

Purpose—This is a descriptive study. It determined the annual, national incidence of head injuries (traumatic brain injury, TBI) to adults and children in motor vehicle crashes. It evaluated NASS-CDS for exposure and incidence of various head injuries in towaway crashes. It evaluated 3 health databases for emergency department (ED) visits, hospitalizations, and deaths due to TBI in motor vehicle occupants.

Methods—Four databases were evaluated using 1997–2010 data on adult (15+ years old) and child (0– 14 years old) occupants in motor vehicle crashes: (1) NASS-CDS estimated the annual incidence of various head injuries and outcomes in towaway crashes, (2) National Hospital Ambulatory Medical Care Survey (NHAMCS)-estimated ED visits for TBI, (3) National Hospital Discharge Survey (NHDS) estimated hospitalizations for TBI, and (4) National Vital Statistics System (NVSS) estimated TBI deaths. The 4 databases provide annual national totals for TBI related injury and death in motor vehicle crashes based on differing definitions with TBI coded by the Abbreviated Injury Scale (AIS) in NASS-CDS and by *International Classification of Diseases* (ICD) in the health data.

Results—Adults: NASS-CDS had 16,980 ± 2,411 (risk = 0.43 ± 0.06%) with severe head injury (AIS 4+) out of 3,930,543 exposed adults in towaway crashes annually. There were 49,881 ± 9,729 (risk = 1.27 ± 0.25%) hospitalized with AIS 2+ head injury, without death. There were 6,753 ± 882 (risk = 0.17 ± 0.02%) fatalities with a head injury cause. The public health data had 89,331±6,870 ED visits, 33,598±1,052 hospitalizations, and 6,682±22 deaths with TBI. NASS-CDS estimated 48% more hospitalized with AIS 2+ head injury without death than NHDS occupants hospitalized with TBI. NASS-CDS estimated 29% more deaths with AIS 3+ head injury than NVSS occupant TBI deaths but only 1% more deaths with a head injury cause. Children: NASS-CDS had 1,453 ± 318 (risk = 0.32 ± 0.07%) with severe head injury (AIS 4+) out of 454,973 exposed children annually. There were 2,581 ± 683 (risk = 0.57 ± 0.15%) hospitalized with AIS 2+ head injury, without death. There were 466 ± 132 (risk = 0.10 ± 0.03%) fatalities with a head injury cause. The public health data had 19,251 ± 2,803 ED visits, 3,363 ± 255

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hospitalizations, and 488 ± 6 deaths with TBI. NASS-CDS estimated 24% fewer hospitalized children with AIS 2+ head injury without death than NHDS hospitalization with TBI. NASS-CDS estimated 31% more deaths with AIS 3+ head injury than NVSS child deaths but 5% fewer deaths with a head injury cause.

Conclusions—The annual national incidence of motor vehicle–related head injury (TBI) was estimated using 1997–2010 NASS-CDS from the Department of Transportation and NHAMCS (ED visits), NHDS (hospitalizations), and NVSS (deaths) from the Department of Health and Human Services. The transportation and health databases use different definitions and coding, which complicates direct comparisons. Future work is needed where ICD to AIS translators are used if comparisons of serious head injuries in NASS and health data sets are to be made.

Keywords

Head injury; TBI; motor vehicle crashes; emergency department visits; adult and children injury

Introduction

Traumatic brain injury (TBI) is a type of head injury that disrupts the brain (Centers for Disease Control and Prevention [CDC] 1999 Centers for Disease Control and Prevention [CDC] 2003). Complications from TBI may result in changes affecting thinking, sensation, language, or emotions and may not be readily apparent. It is a serious public health and safety problem that can lead to death and lifelong disability. Common causes of TBI include motor vehicle crashes, falls, and assaults. Understanding the scope of TBI is essential for developing prevention efforts and identifying education and research priorities. However, quantifying the number of TBIs in the United States is challenging.

Coronado et al. (2011, 2012) determined the average annual incidence of TBI in the United States using CDC multiple-cause-of-death public use data files, which contain death certificate data from all 50 states and the District of Columbia during 1997–2007 and 1995–2009. TBIs from motor vehicle crashes were estimated to result in 218,936 emergency department (ED) visits, 56,864 hospitalizations, and 16,402 deaths annually. These estimates provided no further breakdown by TBI type or age group; crash type was provided for 3 categories: Motor vehicle occupant, motorcycle, and pedestrian crashes. Faul et al. (2010) determined the annual incidence of TBI using National Hospital Discharge Survey (NHDS), National Hospital Ambulatory Medical Care Survey (NHAMCS), and National Vital Statistics System (NVSS) for 2002–2006. Their analysis included estimates of TBI among motor vehicle occupants by age group. They found the average annual incidence of ED visits for child occupants (0–14 years old) was 13,380, with 3,897 hospitalizations and 505 deaths. For adult occupants (15+ years old), the annual incidence of ED visits was 90,986, with 34,151 hospitalizations and 7,076 deaths. Neither study provided information by TBI type or severity. There have been other studies of TBI using various state health databases and injury definitions (Gujral 2007; Leibson et al. 2011; Sears et al. 2013).

The Coronado et al. (2011) and Faul et al. (2010) studies were based on data that used diagnostic coding and external cause of injury coding from the *International Classification of Diseases* (ICD) to identify TBI cases. Previous research has shown that TBI incidence based on ICD methodology has led to underreporting of TBIs. Carroll et al. (2012) found that ICD coding of skull fracture and intracranial hemorrhage produced sensitivity and specificity values greater than 80%, but other types of TBI (e.g., fracture of the vault or base of the skull, intracranial injury including concussion or contusion) had substantially lower sensitivity. Underreporting may be particularly acute for mild TBIs such as concussion. For example, Bazarian et al. (2006) found a sensitivity of only 46% for mild TBI in an ED setting.

Motor vehicle crashes are a common cause for TBI. They provide a unique opportunity to explore different national databases of information on head injury (TBI) incidence using data from transportation and health sources. The purpose of this study was 2-fold: First, to build on the work of Faul et al. (2010) by providing estimates of the annual incidence of various types and severities of TBI among adult and children occupants in motor vehicle crashes and, second, to determine estimates generated from transportation crash data and health data from ED visits, hospital discharge records, and death certificates. The work provides a first effort to determine estimates using the same time frame from automotive and medical data on head injuries and fatalities.

Methodology

In this study, NASS-CDS data was analyzed using Abbreviated Injury Scale (AIS) codes to identify various types and severities of head injury resulting in hospitalization or death. The health data were analyzed by ICD codes that do not have a specific injury severity. The available information from each data set is presented. The only direct comparison that can be made between the transportation and health data sets involves occupants killed in crashes. Comparisons involving nonfatal injuries cannot reasonably be performed without using the ICD to AIS translator. There was no attempt to translate the ICD to AIS levels or to infer an injury severity. These differences make it difficult to compare the crash and health data.

Crash data source

The NASS-CDS is a stratified, multiphase, unequal selection probability sample of motor vehicle crashes that are prospectively selected for in-depth investigation (NHTSA 1997, 2009 NHTSA 2014). Most of the vehicles were towed from the scene because of damage. The data include information based on crash investigation teams that gather information from the crash site, vehicle, medical records, police accident report, and personal interviews. NASS-CDS data for calendar years 1997–2010 were included for all motor vehicle occupants in light vehicles irrespective of model year, seating position, crash type, belt use, or ejection status. The data for calendar years 2009–2010 are representative of model year 2000+ vehicles.

Injury severity and type

Injury was assessed taking into account several factors: (1) body region, (2) specific anatomical structure, (3) type of anatomical structure, (4) level of injury, and (5) severity (minor to maximum). Two scales, the AIS and the Maximum Abbreviated Injury Scale (MAIS), were used to assign numerical injury severity scores, both of which are generated from an original set of ICD codes for each patient record. The AIS is an anatomically based coding system used to describe and classify the severity of injuries. Scores for AIS range from 1 = minor injury to 6 = maximum. In the case of multiple injuries, the highest severity score for all body regions is termed the Maximum Abbreviated Injury Score. MAIS represents the injury severity at the time of first medical evaluation and not long-term consequences (Gennarelli and Wodzin 2005). It ranges from MAIS 0 to 9, where MAIS 9 is an injury with unknown severity. MAIS 1–2 represents minor to moderate injury, MAIS 3 represents serious injury, and MAIS 4–6 represents a severe to maximum injury. Fatalities were defined using the treatment and injury severity variable (TREATMNT in (1) or INJSEV in (4)).

Types of head injury included, for example, concussion, diffuse axonal injury (DAI), and skull fracture, classified as more severe than minor injury (AIS = 1). These 3 types of head injury are not meant to include all TBIs but are instead a subset of TBIs. Other head injuries are included. Head injuries that are catalogued in NASS-CDS typically involve a visit to the ED (NHTSA 1997, 2009). In order to facilitate replication in future studies, types of head injury are defined with AIS scores, variable names, and eligible values.

They were defined as follows:

- *Concussion* was classified as moderate to serious injury (AIS 2–3), to the brain (region 90 = 1 (head), with specific anatomical structure (struspec = 0, 2, 4, 6, 8, 10), and anatomical structure (strutype = 6).
- *DAI* was classified as severe to critical injury (AIS 4–5) to the brain (region 90 = 1 (head), with
- specific anatomical structure ((struspec 0, 2, 4, 6, 8, 10) and anatomical structure (strutype = 6)) or
- specific anatomical structure (struspec 2, 4) and anatomical structure (strutype = 4) and injury level (injlevel = 6)) or
- specific anatomical structure (struspec = 6) and injury level (injlevel = 28)).
- *Skull fracture* was typically classified as moderate to maximum injury (AIS 2+), to the skull (region90 = 1 (head), with specific anatomical structure (struspec 0, 2, 4), and anatomical structure (strutype = 5 (skeletal).

A separate category of severe TBIs was defined using only the AIS score and body region:

- *AIS 4+*: severe to critical injury (AIS 4–5), to the head (region 90 = 1 (head)).

NASS-CDS cases describe occupant injuries by body region, type, injury severity, and source. In some cases, an occupant could have more than one AIS 4+ head injury. The total number of head injuries was determined as well as the number of occupants with a particular type and severity of head injury. The AIS has changed over the years. For example, NASS-CDS transitioned from AIS98 to AIS08 in 2010 (NHTSA 2014). In this study, AIS98 definitions were used because it was available for all years. The effect of using AIS08 coding was not investigated.

The number of occupants who were hospitalized and who sustained a fatal head injury was determined in the transportation and health data sources. A hospitalization (H) was defined as lasting for one day or longer (HOSPSTAY: 1–61). A fatally injured occupant with a head injury (fatal with cause 1–3) was defined using the TREATMNT = 1 variable, which signified that the occupant was fatally injured and not transported to the hospital or the police-reported INJSEV = 4 variable that signified a fatality from the police accident report and the CAUSE = 1–3 variable that signified head injury was listed as a cause of death.

Occupant head injuries were classified by groupings defined here and based on methodologies described by Atkinson et al. (2004) and Hallman et al. (2011):

- Concussion: represents the number of occupants with a concussion.
- Skull fracture: represents the number of occupants with a skull fracture.
- AIS 4+: represents the number of occupants with an AIS 4+ head injury.
- DAI: represents the number of occupants with a diffuse axonal injury.
- AIS 2+H: represents the number of occupants with an AIS 2+ head injury with hospitalization (HOSPSTAY: 1–61).
- AIS 2+H w/o F: represents the number of occupants with an AIS 2+ head injury with hospitalization and who do not have a fatality. TBI without fatality was coded to compare with ED visit and hospitalization health data consistent with Haskins et al. (2013).
- AIS 2+w/ F: represents the number of occupants with an AIS 2+ head injury and a fatality.
- AIS 3+H: represents the number of occupants with an AIS 3+ head injury with hospitalization (HOSPSTAY: 1–61).
- AIS 3+H w/o F: represents the number of occupants with an AIS 3+ head injury with hospitalization and no fatality.
- AIS 3+ w/ F: represents the number of occupants with an AIS 3+ head injury and a fatality.
- F w/ head as cause of death: represents the number of fatal occupants with TBI listed as a cause of death (CAUSE: 1–3).

Severely injured occupants were defined as those with MAIS 4–6 or fatality, because fatalities can occur at any MAIS level. The shorthand notation for this is MAIS 4+F. MAIS 1–2 and MAIS 3 represent occupants without a fatality by moving fatalities at these MAIS levels into the MAIS 4+F category. NASS-CDS records the cause of death from the death record or the coder identifies the cause of death from available injury information from the medical records.

Weighting

National estimates for the number of occupants and injuries in each category were made using the ratio weight (ratwgt) variable in the NASS-CDS provided by the NHTSA. All calculations were based on weighted values and estimates are displayed with standard error. Standard errors were calculated using the SAS procedure "SURVEYFREQ" accounting for PSU (primary sampling unit) and ratio weight factors. SAS software, Version 9.3, was used (SAS Institute 2013). The small sample size of some NASS-CDS estimates produced large standard errors, which are reported with the estimates.

Analyses

The risk that an occupant experiences head injury in NASS-CDS was determined by dividing the number of occupants with a particular head injury by the number of occupants with known injury status, MAIS 0–6 or F (MAIS 0+F). This gives the risk that an occupant experienced injury, such as concussion, AIS 4+ head injury, DAI, or skull fracture, out of all vehicle occupants in towaway crashes.

Health data sources

Three sets of data were used to estimate the annual number of TBIs occurring in 1997–2010. Emergency department visits were estimated using the NHAMCS (2013). This survey is designed to collect data on the use and provision of ambulatory care services in hospital emergency and outpatient departments. It is a national probability sample of visits from hundreds of facilities across the United States. Multiple visits for the same TBI were not counted more than once.

Hospitalizations were estimated using the NHDS (National Center for Health Statistics 2013b). This survey is also designed to collect data at the national level and uses a probability sampling design. It provides information on the characteristics of inpatients discharged from non-federal short-stay hospitals in the United States. Only hospitals with an average length of stay of fewer than 30 days for all patients, general hospitals, or children's general hospitals are included in the survey.

Fatalities were counted using the multiple cause of death data from the NVSS (CDC 2011a; NCHS 2013a, 2013b). Death certificates provided information on the immediate and underlying causes of death. For example, cardiac arrest could be recorded as the immediate cause of death; TBI or car crash could be recorded as underlying or contributing causes. Multiple cause of death data enabled deaths due to crashes to be identified using these contributing cause of death variables. Physicians complete death certificates and rely on knowledge of the patient and chart history and sometimes that physician may not have full knowledge of the injury cause.

Injury severity and type

Severity and type of head injury were identified differently in the health data than the crash investigation data. External cause codes or "E-codes" were used to determine motor vehicle events using the established E-code framework (ecode matrix 2003; ICD-9-CM: E810−E819 (.0, .1) and ICD-10 cause codes were V30−V79 (.4−.9), V81.1, V82.1, V83 V86 (.0 .3). For this report, TBI-related cases were identified−if one of−the diagnosis fields contained an ICD, Clinical Modification, Version 9 (800.0−801.9, 803.0−804.9, 850.0−854.1, 950.1−950.3, 995.55, 959.01) diagnostic code or an ICD-10 diagnosis code for TBI

(S01.0−S01.9, S02.0, S02.1, S02.3, S02.7−S07.0, S02.9, S04.0, S06.0−S06.9, S07.1, S07.8, S07.9, S09.7 S09.9, T01.0, T02.0, T04.0, T06.0, T90.1, T90.2, T90.4, T90.5, T90.8, T90.9), consistent with TBI definitions used by the CDC (CDC 2011b; Faul et al. 2010). The E-code classification is made irrespective of whether a crash meets the towaway classification used by NASS-CDS and ICD codes are not AIS codes, which are potential complicating factors.

Weighting

National estimates for both ED visits and hospitalizations were produced using the weighting variables provided in the NHAMCS and NHDS data files. Transfers and deaths that occurred in the ED or hospital were excluded in order to avoid double counting. Because nearly all deaths are recorded in the United States, the fatality data are considered a census and were not weighted.

Results

NASS-CDS

Table 1 shows the annual count of motor vehicle–related head injury based on 14 years of NASS-CDS from 1997 to 2010. The number of occupants exposed to towaway crashes is given as well as the maximum injury severity (MAIS). The data are divided into adults (15+ years old) and children (0–14 years old). It provides annual national counts by injury severity and head injury type, including concussions, skull fracture, AIS 4+ head injury, and DAI. NASS-CDS also provides counts for hospitalizations and fatalities with AIS 3+ shorthand and AIS 2+ injuries (with notation AIS 3+ w/F head and AIS 2+ w/F) and for fatalities with TBI listed as a cause.

There were an estimated 4,385,517 motor vehicle occupants annually involved in towaway crashes during the study period, including 3,930,543 adults and 454,973 children aged 0– 14 years. Occupants with head injury were most likely to experience concussions (72,856±17,607, risk=1.66±0.40%). There were 18,433 ± 2,654 (risk = 0.42 ± 0.06%) vehicle occupants with severe head injury (AIS 4+) and 11,949 ± 1,667 (risk = 0.27 ± 0.04%) skull fractures. There were 9,250 ± 1,563 (risk = 0.21 ± 0.04%) with AIS 3+ w/F head injury and 10,274 ± 1,774 occupants fatally injured (risk = 0.23 ± 0.04%) with AIS 2+ F head injury. There were 7,220 ± 992 fatally injured occupants due to a head injury using the CAUSE variable for identification.

There were 16,980 ± 2,411 (risk= 0.43 ± 0.06%) adults with AIS 4+ head injury based on 3,930,543 ± 368,582 exposed to towaway motor vehicle crashes annually, on average. There were 70,424 ± 16,859 (risk = 1.79 ± 0.43%) adults who experienced concussion and 10,760 ± 1,481 (risk = 0.27 ± 0.04%) skull fractures. There were 8,622±1,366 (risk=0.22±0.03%) adults fatally injured with AIS 3+ head injury and 9,632 ± 1,587 (risk = 0.25 ± 0.04%) with AIS 2+ head injury. Additionally, there were 6,753 ± 882 (risk= 0.17 ± 0.02%) deaths with head injury listed as a cause of death. There were 49,881 ± 9,729 (risk = 1.27 ± 0.25%) hospitalized adults with AIS 2+ head injury, without death (AIS 2+Hw/o F).

There were 1,453 ± 318 (risk = 0.32 ± 0.07%) children with AIS 4+ head injury based on 454,973 ± 59,455 exposed to motor vehicle crashes annually, on average. There were 2,432

± 785 (risk = 0.53 ± 0.17%) concussions and 1,189 ± 245 (risk = 0.26 ± 0.05%) skull fractures. There were 2,581 ± 683 (risk = 0.57 ± 0.15%) hospitalized children with AIS 2+ head injury without death (AIS 2+ H w/o F). Among the different ways to categorize fatalities, there were 628 ± 215 (risk= 0.14 ± 0.05%) children killed with AIS 3+ head injury (AIS 3+ F) and 642 ± 212 (risk = 0.14 ± 0.05%) killed with AIS 2+ head injury (AIS 2+ F). There were 466 ± 132 fatally injury children who died from a head injury cause.

NHAMCS

Table 2 summarizes information on TBI-related ED visits from the NHAMCS. Three estimates are provided for TBI, including motor vehicle occupants, all motor vehicle injuries (occupants, pedestrians, pedalcyclists, motorcyclists, and others), and ED from all TBI causes. There were 108,582 ± 7,496 TBI ED visits from vehicle occupants, accounting for 48.2% of all motor vehicle related TBI visits and 7.5% of all TBI visits. Table 2 also shows the data for adults and children. There were 89,331 ± 6,870 adults and 19,251 ± 2,803 children with TBI ED visits. Adult occupants were 47.0% of all motor vehicle–related TBI visits and 9.7% of all TBI visits. Child occupants represented 54.4% of the motor vehicle crash–related TBI ED visits.

NHDS

Table 3 provides TBI hospitalization data from the NHDS. There were 36,961 ± 1,082 hospitalizations with TBI among occupants in motor vehicle crashes, accounting for 67.8% of all TBI motor vehicle–related hospitalizations and 14.1% of all TBI hospitalizations. There were 33,598 ± 1,052 adult and 3,363 ± 255 child hospitalizations of motor vehicle occupants. Adult vehicle occupants with TBI were 68.8% of all motor vehicle–related and 14.6% of all TBI hospitalizations.

NVSS

Table 4 shows the deaths from the NVSS. There were 7,170 ± 22 occupant deaths with TBI in motor vehicle crashes. Vehicle occupants were 45.6% of all motor vehicle–related TBI deaths and 13.5% of all TBI deaths. There were 6,682 ± 22 adult and 488 ± 6 child deaths with TBI. Adult vehicle occupants were 45.8% of all motor vehicle–related TBI deaths and 13.2% of all TBI deaths. On average, there were 488 ± 6 child TBI deaths in motor vehicle crashes, accounting for 21.8% of all TBI-related deaths.

National estimates

Though it not possible to directly compare the databases, it is informative to see the differences. For adults, NASS-CDS estimated 48% more hospitalized with AIS 2+ head injury without death than NHDS occupants hospitalized with TBI (49,881 vs. 33,598). NASS-CDS estimated 29% more deaths with AIS 3+ head injury than NVSS occupant deaths (8,622 vs. 6,682) but only 1% more deaths with a head injury cause (6,753 vs. 6,682).

For children, NASS-CDS estimated 24% fewer hospitalized with AIS 2+ head injury without death than NHDS child hospitalization with TBI (2,581 vs. 3,363). NASS-CDS estimated 31% more deaths with AIS 3+ head injuries than NVSS child deaths (642 vs. 488) but 5% fewer deaths with a head injury cause (466 vs. 488).

Discussion

A comparison of the health-related and NASS-CDS databases showed similar numbers of fatally injured children due to head injuries for the same study years. There were 466 ± 132 caused by head injury from NASS-CDS compared to 488 ± 6 from NVSS. However, NASS-CDS estimated 628 ± 215 deaths with AIS 3+ head injury and 642 ± 212 with AIS 2+ head injury annually. This is 31 and 34% higher than NVSS. For adults, NASS-CDS estimated 6,753 ± 882 deaths with a head injury cause compared to 6,682 ± 22 deaths with TBI by NVSS. The estimates are very similar. However, NASS-CDS estimated 29% more deaths of occupants with AIS 3+ head injuries (8,622 ± 1,376) and 45% more deaths with AIS 2+ head injuries (9,632 ± 1,587) than NVSS.

There are a number of possible reasons for the different estimates from NASS-CDS and NVSS. NASS-CDS investigations are usually based on all available medical records for an occupant. The discharge summary is often used and may be the only piece of medical documentation. Nonetheless, a discharge summary generally contains more detailed injury information than a death certificate. The cause of death is extracted from autopsy reports, which may not be accurate or complete. Ermenc (1999) compared the cause of death listed in clinical records and in postmortem examinations and found that only 48.87% were in agreement. Furthermore, the specific cause of death notation in autopsy reports often refer to “blunt force trauma,” which may or may not involve TBI. Rodriguez et al. (2006) reported that TBI deaths, particularly those involving falls and MVC, are not always captured on the death certificate. There are other potential issues (Betz et al. 2008).

In NASS-CDS, fatally injured occupants with head injury were identified by the listing of head injury as one of 3 possible causes of death. Death was defined using TREATMNT = 1 or police injury severity INJSEV = 4. Death can occur within 30 days after the crash and be included in NASS-CDS. A reason for the potential underreporting of deaths in the NVSS is because a death certificate must have the appropriate E-codes applied to the record. Administrative E-coded data are completed 86.2–92% of the time and has been steadily improving (Barrett and Steiner 2014). However, an assessment of E-code accuracy is not possible without studies like this one. E-codes are derived from chart data obtained from the hospital system and included in the death certificate. The NASS-CDS has no requirements but it includes information from hospital records and interviews for serious head injuries and medical examiner reports for fatalities from towaway crashes.

NASS-CDS used AIS to quantify the severity of head injuries. The AIS coding instructions require that head injuries with anatomical lesions must be verified by a computed tomography scan, other diagnostic studies, or autopsy. The health data use a traumatic brain injury designation primarily based on ICD-9- CM codes, not an AIS code. ICD-9-CM coding is a method for medical reimbursement. The severity and type of head injury may be different in the health data than in the crash investigation data. However, all patients with a severe TBI routinely undergo head computed tomography per clinical protocol (Carroll et al. 2010). Patients with TBI are generally admitted to the hospital and would have physician- and nurse-recorded documentation of specific injuries. In this study, it was assumed that occupants with severe head injury (AIS 4+), DAI, or skull fractures would be considered as having a TBI.

The health-related databases estimate 31% more children hospitalized with head injuries than NASS-CDS (3,363 ± 255 from NHDS versus 2,581 ± 683 from NASS-CDS, annually). There are a number of possible reasons for the higher estimate by NHDS, including children taken to a hospital by parents after a crash that is not severe enough to enter the NASS-CDS database. NASS-CDS involves crashes where at least one of the vehicles is towed away. There can be crashes where the vehicle is operational and the parents take the child to the hospital.

This study was a first attempt to associate transportation and health related databases on head injuries (TBI) to vehicle occupants. There are important similarities and some differences in the estimates of annual incidence of head injuries and related deaths of vehicle occupants. The comparisons provided in this study should be considered as a first step assessment and not as a statistical analysis. Additional research on AIS and ICD should be further explored due to the differences in the coding systems' purpose, coding schemas, collection methods, and information used to make final injury determinations. More work is needed to standardize the data entries. The results suggest that a larger sample of cases is also needed within NASS-CDS. The NASS-CDS data do provide a measure of exposure so that risks for head injury (TBI) can be determined based on towaway crashes in the United States.

Limitations

This work represents an initial effort to similarly evaluate motor vehicle crash data collected by NHTSA with health-related databases collected by DHHS. There are a number of limitations in any attempt to compare the estimates. The definitions and identifiers of TBI, treatment, and cause of death are not identical between the data sources. Most of the NHTSA and DHHS databases extract the information from other sources, which are not always the same. The NASS-CDS data sets had small sample sizes and large confidence intervals for some estimates. Some of the data are collected at different times and there is variability due to the sampling techniques and definitions. Nonetheless, the 2 sources offer differences that may provide a basis for improving each database by using common data entries and simplifying linkages in the future. This study is based on national estimates from data from different states. There may be some discrepancies between states. For example, some states may require complete internal exams for fatally injured occupants and some may not.

Injury Severity Score (ISS) = 75 has been used to define death in motor vehicle crashes. This definition was not used here because Weaver et al. (2013) found 17–32% survival rates in patients with various AIS 6 injuries (ISS = 75). This finding was corroborated by Peng et al. (2015),who evaluated the 2006–2010 U.S. Nationwide Emergency Department Sample and found that 48.6% of patients with an ISS = 75 were discharged alive, 25.8% died, and 25.6% had an unknown mortality status. In this study, fatally injured occupants were defined using the treatment and injury severity variable in NASS-CDS. There were 15 additional unweighted cases with ISS = 75. Each case was reviewed. Fourteen of the cases were not fatal. The fatality case (2001-72-71K) involved multiple organ failures associated with a critical spinal cord injury. The survival rate was 99.4% with ISS = 75 head injury based on weighted data in the NASS-CDS sample.

Annual count data were presented in this study. In the NASS-CDS analysis, the annual count was determined by taking the total weighted counts and dividing by 14 years. The data for 1997 to 2008 were based on all model years. However, the data for 2009 and 2010 did not include vehicles with model years older than 10. The NASS-CDS annual counts are thus an estimate.

There was no attempt to translate the ICD data or to infer an injury severity in this study. Barell et al. (2002) proposed a translator for ICD conversion to injury severity. Linkage projects using comprehensive administrative data sets have used ICD to AIS translators as a means of comparing and compiling injury severity information. Though Corrigan et al. (2014) found that Barell matrix coding did a poor job of converting ICD to injury severity for TBI, additional work is needed where ICD to AIS translators are used, if comparisons of serious head injuries in NASS and health data sets are to be made (Loftis et al. 2016).

There are a number of other data sets that could be used to explore differences between crash and hospital data. Although not investigated in this study, the National Trauma Data Bank from the American College of Surgeons provides AIS and ICD codes for patients admitted to a representative sample of trauma centers. The National Electronic Injury Surveillance System from the Consumer Product Safety Commission and Nationwide Emergency Department Sample developed for the Healthcare Cost and Utilization Project are also potential data sources to estimate the prevalence of head injuries treated in the ED in addition to NHAMCS. In addition, NASS-CDS and Crash Injury Research (CIREN) systems collect both ICD and AIS, which may provide a useful further area of study, because each system has merit and usefulness.

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Table 1

Annual count of head injuries to motor vehicle occupants from 1997–2010 NASS-CDS

Motor Vehicle Occupants	Children	Adults	All
Annual Incidence	**0-14**	**15+**	
Exposed to towaway crash	454,973	3,930,543	4,385,517
se	59,455	368,582	421,642
Maximum injury			
MAIS 1-2	114,732	1,433,493	1,548,225
se	20,296	168,808	186,367
MAIS 3	2,289	57,870	60,159
se	664	10,114	10,694
MAIS4+F	2,309	43,989	46,298
se	529	7,773	8,250
Fatals	994	22,083	23,076
se	286	3,760	4,025
Occupants with head injury			
Concussion	2,432	70,424	72,856
se	785	16,859	17,607
Skull Fractures	1,189	10,760	11,949
se	245	1,481	1,667
AIS4+	1,453	16,980	18,433
se	318	2,411	2,654
DAI	466	4,058	4,523
se	195	1,117	1,170
AIS2+H	2,737	51,893	54,630
se	699	10,115	10,697
AIS2+H w/o F	2,581	49,881	52,462
se	683	9,729	10,292
AIS2+w/F	642	9,632	10,274
se	212	1,587	1,774
AIS3+H	1,410	18,928	20,338
se	370	2,691	2,883
AIS3+H w/o F	1,382	18,727	20,109
se	345	2,699	2,858
AIS3+w/F	628	8,622	9,250
se	215	1,366	1,563
Fatal with cause 1-3 = head	466	6,753	7,220
se	132	882	992

NASS: National Automotive Sampling System.

CDS: Crashworthiness Data System.

TBI: Traumatic Brain Injury, H: Hospitalized, F: Fatal, se: standard error.

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Table 2

Annual count of TBI visits to the emergency department from 1997–2010 NHAMCS

Annual incidence ED visits	Children 0–14	Adults 15+	All
MV occupants with TBI	19,251	89,331	108,582
se	2,803	6,870	7,496
All MV with TBI[a]	35,374	190,023	225,397
se	4,171	10,575	11,759
All TBI causes	525,672	924,417	1,450,089
se	27,972	38,626	59,805

[a]Includes all occupants, pedestrians, motorcylists, pedalcyclists, and others.

Table 3

Annual count of TBI hospitalizations from 1997–2010 NHDS

Annual incidence Hospitalized	Children 0–14	Adults 15+	All
MV occupants with TBI	3,353	33,598	36,961
se	255	1,052	1,082
All MV with TBI[a]	5,693	48,851	54,544
se	316	1,295	1,331
All TBI causes	32,332	230,693	263,025
se	930	2,679	2,817

*Includes all occupants, pedestrians, motorcylists, pedalcyclists, and others.

Table 4

Annual count of TBI deaths from 1997–2010 NVSS

Annual incidence Fatal	Children 0–14	Adults 15+	All
MV occupants with TBI	488	6,682	7,170
se	6	22	22
All MV with TBI*	1,130	14,579	15,709
se	9	31	33
All TBI causes	2,239	50,789	53,028
se	13	55	56

[a] Includes all occupants, pedestrians, motorcylists, pedalcyclists, and others.