HHS Public Access

Author manuscript

J Occup Environ Med. Author manuscript; available in PMC 2014 May 01.

Published in final edited form as:

J Occup Environ Med. 2013 May ; 55(5): 507–513. doi:10.1097/JOM.0b013e31827ee018.

Case Identification of Work-Related Traumatic Brain Injury Using the Occupational Injury and Illness Classification System (OIICS)

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Abstract

Objective—Traumatic brain injury (TBI) is one of the most common, costly, and disabling occupational injuries. Objectives included determining whether work-related TBI could be reliably identified using the Occupational Injury and Illness Classification System (OIICS) and describing challenges in developing an OIICS-based TBI case definition.

Methods—Washington State trauma registry reports and workers' compensation claims were linked (1998–2008). Trauma registry diagnoses were used as the gold standard for six OIICS-based TBI case definitions.

Results—OIICS-based case definitions were highly specific but had low sensitivity, capturing less than a third of fatal and nonfatal TBI.

Conclusions—The use of OIICS versus ICD-9-CM codes underestimated TBI and changed the attributable cause distribution, with potential implications for prevention efforts. Surveillance methods that can more fully and accurately capture the impact of work-related TBI across the U.S are needed.

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Conflicts of Interest
No conflicts of interest were reported by the authors.

Keywords

occupational injuries; traumatic brain injury; workers' compensation; trauma registries; OIICS; underreporting; injury surveillance; sensitivity and specificity; case definition; case ascertainment

Approximately 1.7 million people sustain traumatic brain injuries (TBI) each year in the U.S.[1] These injuries result in sizable direct and indirect costs; recent estimates suggest that the annual cost burden of TBI in the U.S. is well over $75 billion.[2,3] TBI is one of the most common and costly occupational injuries.[4,5] A recent study of work-related TBI fatalities in the U.S. found that TBI accounted for 22% of all work-related injury fatalities between 2003 and 2008, and 46% of work-related fatal falls.[6] The costs of acute and long-term care, long-term disability, rehabilitation, lost wages, and productivity are enormous, exacerbated by the high incidence of work-related TBI in younger workers.[7,8] Beyond the financial ramifications of TBI, injured workers may experience long-term cognitive, physical, psychosocial, and emotional health consequences.[8,9] Many workers with TBI never return to work.[8] Yet few U.S.-based studies have focused on work-related TBI, and no national estimates of the incidence of nonfatal occupational TBI were identified. This deficiency is due in part to the difficulty inherent in reliably identifying work-related TBI using administrative data sources.[6]

The CDC has published case definitions for TBI using ICD-9-CM and ICD-10 codes, which are commonly used in injury research.[1,10] However, in the U.S., national estimates of fatal and nonfatal occupational injuries generally rely on the Bureau of Labor Statistics (BLS)' Census of Fatal Occupational Injuries (CFOI) and Survey of Occupational Injuries and Illness (SOII). Both of these surveillance systems, as well as many workers' compensation (WC) databases, rely on the Occupational Injury and Illness Classification System (OIICS) to classify injuries.[11] The OIICS was developed by the BLS to provide a standardized coding system for characterizing work-related injuries and illnesses. The OIICS has five subcomponent structures that characterize the injury and its circumstances (i.e., nature, part of body affected, source/secondary source, and event or exposure).[11] No guidelines exist for case ascertainment of fatal or nonfatal TBI using the OIICS, but recent progress has been made in estimating the national incidence of fatal occupational TBI using CFOI data in combination with an OIICS-based case definition.[6]

The structure of the OIICS requires coders to identify the most severe injury and default to multiple injury/multiple body part categories when there is conflict or insufficient information, which can obscure the presence of individual injuries such as TBI. An apparent undercount of TBI using the OIICS when compared with ICD-9-CM codes was noted in previous work by this article's first author.[12] This motivated further exploration of this issue using the clinical diagnosis information available from a state trauma registry, linked with WC claims containing OIICS codes. Though state-specific, this provided a gold standard to assess the potential undercount of TBI inherent in relying on the OIICS. Underestimating the prevalence of such a potentially severe and disabling injury could have important ramifications for prevention efforts.

The aims of this study were to: (1) determine whether TBI can be reliably identified using existing OIICS codes, (2) describe the accuracy and completeness of case classification and case-finding for various OIICS-based case definitions, using clinically-identified TBI in trauma registry data as the gold standard, (3) enumerate TBI cases contained in various combinations of OIICS nature and part of body codes, (4) describe whether OIICS-based case definitions more reliably identify isolated TBI compared with TBI in combination with other traumatic injuries, or fatal TBI compared with nonfatal TBI, and (5) explore and describe challenges with respect to developing an OIICS-based case definition for TBI and the potential implications for surveillance and prevention efforts.

METHODS

Study Population and Data Sources

Data for injuries occurring from 1998 through 2008 were obtained from: (1) the Washington State Trauma Registry (WTR), maintained by the Washington State Department of Health, and (2) WC claims, maintained by the Washington State Department of Labor and Industries (L&I). This study was approved by the Washington State IRB.

The WTR contains reporting data for traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma facilities. For most of the years of this study, reports were mandatory for adult patients who (1) were discharged with ICD-9-CM diagnosis codes of 800–904 or 910–959 (injuries), 994.1 (drowning), 994.7 (asphyxiation), or 994.8 (electrocution), and (2) met at least one of the following criteria: trauma resuscitation team activation, dead on arrival, death during the emergency department (ED) visit or associated hospital stay, interfacility transfer by Emergency Medical Services (EMS) or ambulance, or inpatient admission of at least 48 hours. The WTR contains no information about occupation or industry, but does contain a work-relatedness field that has been shown to be highly sensitive and specific in identifying work-related injuries.[13] In a nationwide survey conducted in 2004 by Mann, et al., the WTR trauma manager estimated that the WTR captured about 85% of trauma victims with injuries satisfying registry inclusion criteria.[14] However, the WTR does not capture data for the many occupational injuries that do not meet inclusion criteria.[15] In addition, occupational fatalities can occur in any setting and only those occurring after contact with the EMS and trauma system are reported to the WTR.[5]

Washington State has a single payer WC system (the State Fund) that covers approximately 70% of workers specified by the Industrial Insurance Act.[16] Self-insured employers account for the remaining 30%. Compensable State Fund and self-insured WC claims were obtained from L&I, excluding injuries among workers younger than 16 and injuries occurring outside Washington State. (Compensable WC claims include claims for fatalities, total permanent disability, and those involving compensation for work missed due to the injury.) The study excluded WC claims with special confidentiality-related restrictions and medical aid-only claims. Medical aid-only claims cover medical treatment but do not involve time-loss payments because the injury did not cause any missed work days after the initial three-day post-injury waiting period. A preliminary assessment found that very few medical aid-only claims linked to the relatively severe traumatic injuries reported to the WTR.

Records were linked and deduplicated using The Link King, a public domain software program developed in Washington State for deterministic and probabilistic linkage of administrative records.[17] Direct personal identifiers were available for the linking procedures. All non-exact matches were reviewed by the first author for plausibility. This resulted in 6,673 work-related injury events (for 6,645 workers) having both WTR and WC data available. Further detail about the data sources and linkage procedures can be found in previous publications.[13,18]

Measures

TBI was identified following the CDC case definition: the presence of any ICD-9-CM code of 800.0–801.9, 803.0–804.9, 850.0–854.1, 950.1–950.3, or 959.01 in any of the 27 WTR ICD-9-CM diagnosis fields.[1,10] These codes were generated for clinical descriptive purposes, generally by the trauma surgeons and/or trauma registrars (in contrast to the ICD-9-CM codes in hospital discharge or workers' compensation data that are generated primarily for billing purposes). The WTR has conducted periodic validity studies assessing factors such as coding accuracy. The software used by the hospitals to collect and submit data to the registry contains logic checks and error checks that facilitate data quality and completeness.

Isolated TBI was defined as TBI that did not have any maximum Abbreviated Injury Scale (AIS) score greater than 1 (no more than minor injury) in body regions other than the head/neck, as well as no indication of additional moderate extracranial injury in the head/neck region (e.g., facial fractures, cervical spine injuries). TBI with other trauma was defined as TBI that had at least one maximum AIS score greater than 1 in a body region other than the head/neck or an ICD-9-CM code in the head/neck region indicating at least moderate extracranial injury.

Fatalities were defined as workers who died prior to or during the initial hospitalization according to WTR data, or whose WC claim was classified as a fatality. Fatalities would not be captured by the WTR if there was no trauma hospital involvement (e.g., direct transport to a morgue or coroner). Cause of injury was based on the ICD-9-CM external cause of injury codes (E codes) from WTR records and categorized according to CDC recommendations.[19]

L&I uses the 2007 version of the OIICS to identify and record injury/illness characteristics.[20] OIICS codes were available for essentially all State Fund and self-insured claims. Due to missing OIICS nature of injury or part of body codes, 34 injury events (0.5%) were excluded from these analyses (9 were nonfatal TBI cases and 3 were fatal TBI cases).

Solely for purposes of this study, six OIICS-based TBI case definitions were defined as shown in Figure 1. Case definition 1 (CD1) was the narrowest, and CD2 through CD6 were progressively less restrictive (CD6 was so loose as to arguably be meaningless with respect to TBI, and is presented only for purposes of illustration).

Data Analysis

WTR-based ICD-9-CM codes were used as the gold standard for identification of TBI cases. Counts of TBI captured by various combinations of OIICS nature and part of body categories were calculated separately for: (1) all TBI, (2) fatal TBI, and (3) isolated TBI. Sensitivity, specificity, area under the curve (AUC) using receiver operating characteristic (ROC) curves, positive predictive value (PV+), and negative predictive value (PV−) were estimated for each of the six case definitions. The number and percent of cases captured by each of the six case definitions were calculated for several subsets of TBI (fatal, nonfatal, isolated TBI, TBI with other trauma).

Analyses were performed using Stata/SE 11.2 for Windows (StataCorp LP, College Station, TX). The Stata user-written program -diagt- was used to calculate case classification statistics.[21]

RESULTS

Overall, 19.8% of work-related injuries reported to the WTR and linked to a WC claim involved TBI. By cause of injury, 36.7% of motor vehicle traffic incidents and 25.4% of falls involved TBI. Among work-related injury fatalities, 59.5% overall involved TBI, as did 88.2% of fatal falls and 66.0% of fatal motor vehicle traffic incidents. Most of the 117 fatal TBI cases were due to falls (51.3%) and motor vehicle traffic incidents (27.4%). Of all linked work-related TBI in this sample, 8.9% were fatal and 91.1% were nonfatal; 34.6% of the sample was isolated TBI and 65.4% was TBI with other trauma.

Figures 2, 3, and 4 display the counts of work-related TBI cases captured by various OIICS nature and part of body combinations, for all TBI (N=1,313), fatal TBI (N=117) and isolated TBI (N=454) respectively. A high proportion of TBI was obscured within the categories of multiple traumatic injuries and/or multiple body parts, particularly for all TBI (Figure 2) and fatal TBI (Figure 3), and even for isolated TBI (Figure 4). This appeared to be the driver for the very low sensitivity exhibited by all case definitions except for CD6, which included the “multiple” categories (Table 1). On the other hand, as shown in Table 1, all case definitions were highly specific (CD6 somewhat less so).

Table 2 shows the number and percentage of work-related TBI cases correctly identified using the six case definitions for several categories of TBI (fatal/nonfatal; isolated/with other trauma). CD1, which served as the initial case definition based on strong face validity, identified only 13% of all fatal/nonfatal TBI. It identified well under a third of isolated TBI and only 6% of TBI with other trauma. CD5 identified less than a third of TBI cases in every TBI category, with the exception of isolated TBI for which it identified 53%. Only CD6, which classified any multiple trauma to multiple body parts as TBI, identified more than two-thirds of TBI cases.

Table 3 presents the attributable cause distribution for work-related TBI using the WTR-based case definition and each of the OIICS-based case definitions (with the exception of CD6, which was defined too broadly for this purpose). All case definitions identified the primary cause of work-related fatal/nonfatal TBI as falls. However, the WTR-based definition identified motor vehicle traffic incidents as the second most frequent cause, while all OIICS-based definitions identified the struck by/against category as the second most frequent cause, with motor vehicle traffic incidents third.

DISCUSSION

This study did not identify any reasonably sensitive OIICS-based case definition for TBI. Though highly specific, all case definitions used in this study had low sensitivity, capturing less than a third of the fatal or nonfatal work-related TBI identified using the clinical diagnoses codes available in the trauma registry (with the exception of CD6, which lacked face validity and was included only for purposes of illustration). A high proportion of TBI was obscured within the categories of multiple traumatic injuries and/or multiple body parts. In addition, OIICS-based case definitions captured only about half of the isolated TBI cases, presumably due to deficiencies in the information available to OIICS coders or coding errors (which might vary by jurisdiction or database).

All of the TBI case definitions used in this study identified the primary cause of work-related fatal/nonfatal TBI as falls. This comports with several studies of occupational TBI conducted in Ontario and Washington State,[7,22,23] and suggests opportunities for prevention. However, the WTR-based definition identified motor vehicle traffic incidents as the second most frequent cause, while all OIICS-based definitions identified the struck by/against category as the second most frequent cause, with motor vehicle traffic incidents in third place. This was likely due to the lower frequency of isolated TBI for motor vehicle traffic incidents (24%) compared with other causes (37%, $p<.0005$). The OIICS is used to identify the most severe injury, which can conflict with the goal of complete surveillance of particular types of injuries for public health planning and injury prevention purposes. Significant TBI can occur in the context of multiple significant injuries, and the injury that is initially judged the most severe may not necessarily be the most costly or disabling long-term.[24,25]

Anderson, Bonauto, and Adams (2010) described similar case ascertainment issues when using another common injury classification scheme, the American National Standards Institute (ANSI) Z16 system, to identify amputations.[26] They found that the use of ANSI Z16 codes alone resulted in an undercount of amputations, affected observed rates and trends, and had the potential to lead to incorrectly/inadequately targeted prevention activities.[26]

The OIICS version 2.0 issued in Sept 2010 (and the minor update 2.01 issued in Jan 2012) contained some changes that may alleviate some of the issues raised here, but probably will not completely resolve them.[27] For example, several additional subcategories of multiple trauma and multiple body parts have been created that specify head involvement, which may reduce the volume of TBI currently captured in nonspecific “multiple” categories. However, many potential head injury combinations remain unspecified. Although CFOI and SOII used this version beginning with year 2011, it is unclear if or when state workers’ compensation programs and other agencies will make the transition.

Strengths and Limitations

This study constitutes a preliminary and novel effort to explore and describe challenges with respect to developing an OIICS-based case definition for fatal/nonfatal TBI and the potential implications for prevention efforts. This study relied on clinical diagnosis codes from a trauma registry combined with WC claims data. Most states maintain a trauma registry, and researchers in several states (e.g., Alaska, Illinois, and Washington) have begun to explore these registries as a resource for occupational injury surveillance and research.[13,18,28–30] However, few states have population-based WC data in addition to a well-developed trauma registry. Leveraging this unusual combination of circumstances is a major strength of this study.

This study relied on a relatively severe group of injuries reported to a trauma registry, and those injured may have been more likely to have sustained TBI and/or multiple injuries compared with a more general occupational injury sample. In this study, about 20% of all injuries and 60% of fatal injuries involved TBI, compared with a CDC estimate that TBI contributes to 31% of all injury-related deaths.[1] An Ontario-based study used coroner's records to determine that TBI contributed to 45% of work-related fatalities.[31] NIOSH researchers found that TBI accounted for 22% of all occupational injury deaths and 46% of fatal falls (note the important distinction between "contributed to" and "accounted for").[6]

We do not presume to recommend any specific OIICS-based case definition for use in TBI surveillance. Doing so would require further expert review for face validity, as well as validation in data sets more representative of the spectrum of occupational injuries. Some of the case definitions used in this study might be less specific for TBI in a broader occupational injury sample. There are many possible combinations of OIICS codes that could be contemplated for inclusion. For example, the case definitions used in this study did not include gunshots to the head for simplicity's sake, although this was done in a NIOSH study of fatal occupational TBI (using nature=036 and part of body=00 or 01 or 08).[6] Doing so would have made little difference for this study; there were only four such cases over all 11 years (all were classified as TBI per WTR data, and two were fatal). It is likely that many such cases were pronounced dead at the scene, never transported to a trauma hospital, and thus never reported to the trauma registry. There are likely other examples of categories that could and should be considered for inclusion in a final TBI case definition.

This study captured only a portion of the work-related TBI in Washington State, and the numbers presented were not intended to describe incidence. This study was limited to traumatic injuries eligible for and included in the WTR and required linkage to a compensable WC claim. Thus, minor injuries, injuries not treated at a designated trauma hospital or not reported to the trauma registry, as well as injuries not reported to WC or not covered by WC (e.g., federal workers, domestic workers, the self-employed, etc.) would not have been included.

CONCLUSIONS

This study casts light on the potential undercount of work-related TBI when a commonly used occupational injury classification system, the OIICS, is relied upon for case-finding.

OIICS-based case definitions captured less than a third of the fatal or nonfatal work-related TBI identified using clinical diagnoses codes available from a trauma registry. Systematic underestimation of the incidence of work-related TBI, an often severe and disabling injury, directly hinders surveillance efforts. In addition, the use of OIICS versus ICD-9-CM codes for case identification, at least in this sample, changed the observed attributable cause distribution, underestimating the contribution of motor vehicle traffic incidents to work-related TBI. This has important implications for the targeting of primary prevention programs and resources. Further research to develop an adequate OIICS-based TBI case definition is indicated, preferably using data sets that are representative of the full spectrum of occupational injuries. However, it is unlikely that any OIICS-based TBI case definition can fully mitigate this potential undercount due to frequently incomplete injury information and issues related to identifying the most severe injury and classifying multiple injuries. As efforts develop to document the incidence and importance of work-related TBI across the U.S., attention must be paid to developing surveillance methods that can more fully and accurately capture its impact.

Acknowledgments

Source of Funding

This study was funded in part by the National Institute for Occupational Safety and Health (NIOSH, 1R03OH009883). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH. Dr. Graves received fellowship support from the National Institute of Child Health and Human Development (T32HD057822).

We gratefully acknowledge Darrin Adams, Barbara Silverstein, and David Bonauto at the Washington State Department of Labor and Industries and Kathy Schmitt, Zeynep Shorter, Mary Rotert, and Susan Reynolds at the Washington State Department of Health Trauma Registry for providing the data and for their extensive and generous explanations of each system and the underlying data generating processes.

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Nature:	Intracranial 06	Intracranial and internal organ 086	Fractures 012				Multiple trauma 08		Symptoms, signs, ill-defined 4		Nonclassifiable 9999	
Body part:	Any	Any	Cranial/ skull 01	Head (not ears/face) 00/01/08	Head 0	Multiple 8	Head 0	Multiple 8	Head 0	Multiple 8	Head 0	Multiple 8
CD1	X	X	X									
CD2	X	X	X	X								
CD3	X	X	X	X	X							
CD4	X	X	X	X	X		X					
CD5	X	X	X	X	X		X		X		X	
CD6	X	X	X	X	X	X	X	X	X	X	X	X

Figure 1.

Occupational Injury and Illness Classification System (OIICS)-based case definition (CD) criteria used for traumatic brain injury (TBI) case classification estimates. Numbers in the first and second rows indicate OIICS nature and body part codes respectively. All existing subgroups of each code shown were subsumed unless otherwise indicated. An “X” indicates each nature/body part combination that was included by the case definition on the same row.

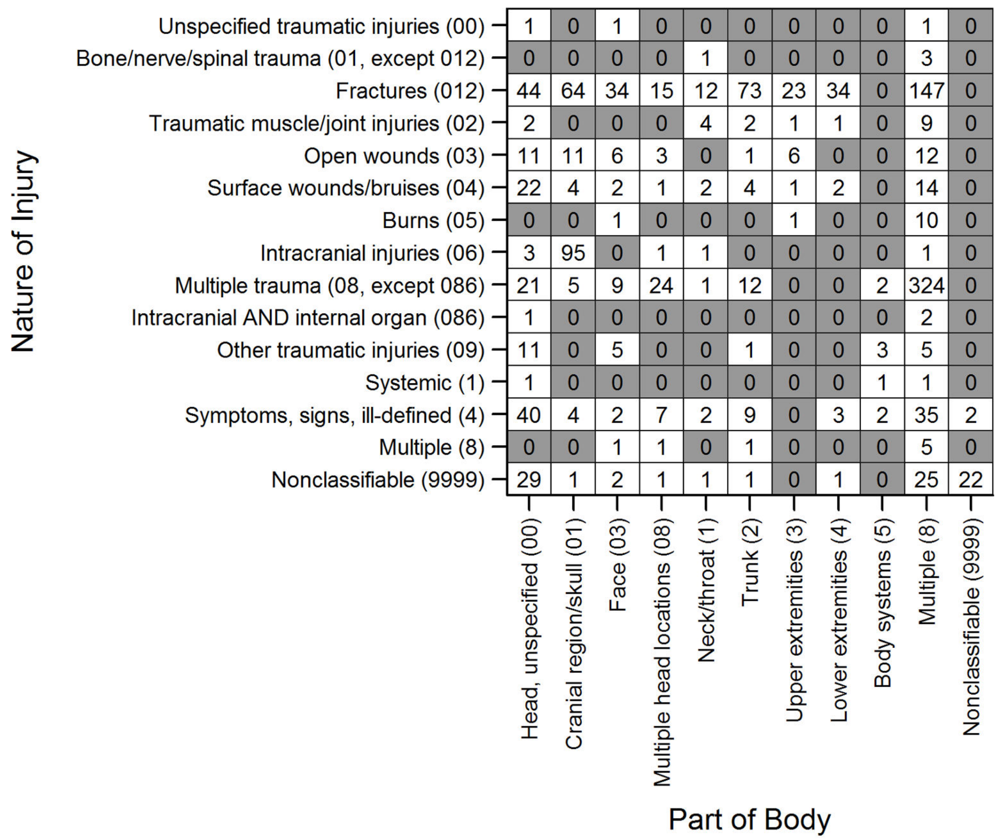

Figure 2.

Count of all traumatic brain injury (TBI) cases captured by each Occupational Injury and Illness Classification System (OIICS) nature/part of body combination (N=1,313). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.

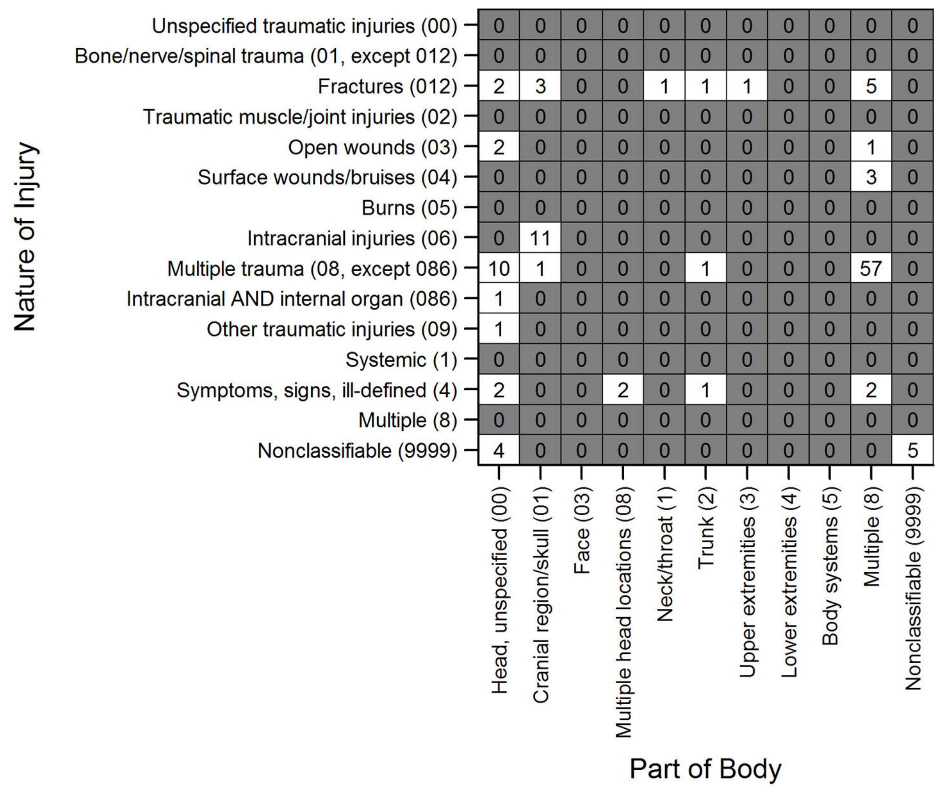

Figure 3.

Count of fatal traumatic brain injury (TBI) cases captured by each Occupational Injury and Illness Classification System (OIICS) nature/part of body combination (N=117). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.

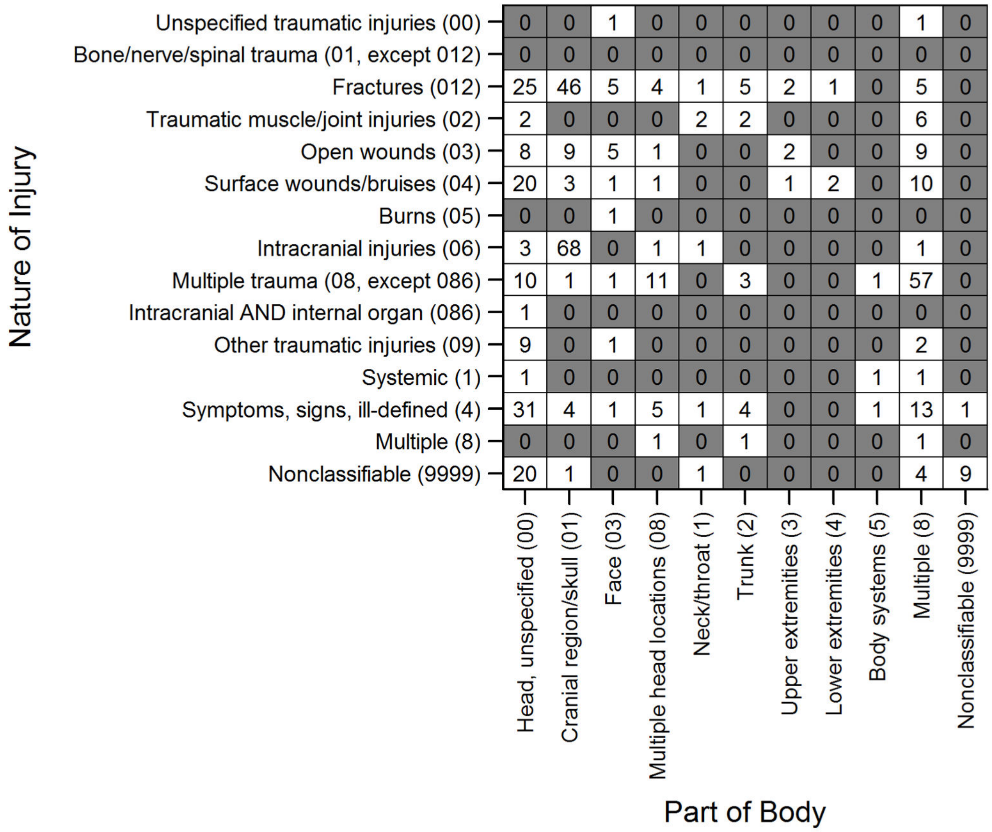

Figure 4.

Count of isolated traumatic brain injury (TBI) cases captured by each Occupational Injury and Illness Classification System (OIICS) nature/part of body combination (N=454). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.

TABLE 1

Case Classification for OIICS-based Case Definitions (N=6,639*)

Case definition (CD)	True positives n	False positives n	Sensitivity	Specificity	AUC	PV+	PV−
CD1	168	17	12.8	99.7	0.56	90.8	82.3
CD2	227	23	17.3	99.6	0.58	90.8	83.0
CD3	261	61	19.9	98.9	0.59	81.1	83.3
CD4	320	70	24.4	98.7	0.62	82.1	84.1
CD5	406	99	30.9	98.1	0.65	80.4	85.2
CD6	937	898	71.4	83.1	0.77	51.1	92.2

* All linked work-related injuries having available OIICS codes.

OIICS, Occupational Injury and Illness Classification System; AUC, area under the receiver operating characteristic curve; PV+, positive predictive value; PV−, negative predictive value; CD, case definition.

TABLE 2

True Positive Cases of Work-Related TBI Identified Using OIICS-Based Case Definitions (CD), by TBI Category

TBI category	TBI* N	CD1 n (%)	CD2 n (%)	CD3 n (%)	CD4 n (%)	CD5 n (%)	CD6 n (%)
All TBI	1,313	168 (12.8)	227 (17.3)	261 (19.9)	320 (24.4)	406 (30.9)	937 (71.4)
Fatal TBI	117	15 (12.8)	17 (14.5)	17 (14.5)	28 (23.9)	36 (30.8)	100 (85.5)
Nonfatal TBI	1,196	153 (12.8)	210 (17.6)	244 (20.4)	292 (24.4)	370 (30.9)	837 (70.0)
Isolated TBI	454	121 (26.7)	150 (33.0)	155 (34.1)	178 (39.2)	240 (52.9)	319 (70.3)
TBI with other trauma	859	47 (5.5)	77 (9.0)	106 (12.3)	142 (16.5)	166 (19.3)	618 (71.9)

*TBI identified using WTR-based ICD-9-CM codes according to the CDC case definition.

TBI, traumatic brain injury; OIICS, Occupational Injury and Illness Classification System; CD, case definition.

TABLE 3

Attributable Cause of Work-Related TBI (Percentage Distribution) for each WTR and OIICS-Based Case Definition (CD)

Cause of injury	TBI* (N=1,313)	CD1 (N=185)	CD2 (N=250)	CD3 (N=322)	CD4 (N=390)	CD5 (N=505)
Motor vehicle traffic	20.4	11.9	10.0	11.2	10.8	10.9
Pedal cyclist, other	0.2	-	-	-	-	0.2
Pedestrian, other	0.5	-	-	0.3	0.3	0.4
Transport, other	3.7	1.6	2.8	2.2	3.1	4.0
Firearm	0.6	-	-	-	-	0.2
Poisoning	-	-	-	-	0.3	0.2
Falls	50.3	58.4	56.4	49.4	46.4	46.9
Fire/burn	0.3	-	-	-	0.3	0.6
Cut/pierce	1.1	1.1	0.8	1.2	1.3	1.8
Struck by/against	14.8	16.2	19.6	24.5	25.6	24.0
Machinery	4.3	8.1	7.2	7.5	7.7	6.7
Natural/environmental	0.3	0.5	0.4	0.3	0.3	0.4
Other specified	2.9	1.6	2.0	2.8	3.3	3.2
Other specified, NEC	0.2	0.5	0.4	0.3	0.5	0.4
Unspecified	0.3	-	0.4	0.3	0.3	0.2

*TBI identified using WTR-based ICD-9-CM codes according to the CDC case definition.

TBI, traumatic brain injury; WTR, Washington State Trauma Registry; OIICS, Occupational Injury and Illness Classification System; CD, case definition; NEC, not elsewhere classifiable.