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Under-Reporting of Focal Brain Injuries in Emergency Department Records vs. Hospital Inpatient Records within the National Trauma Data Bank

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14. ABSTRACT

The objective of this research was to investigate the prevalence of skull fracture and focal brain (FB) injury between emergency department (ED) and hospital inpatient records (HOSP) of the National Trauma Databank from 2013 to 2015 to identify if there was a difference in the types of head injury (HI) identified and associated with fatalities.
A retrospective cohort design of military-aged adults (ages 17–55) was used to study incidence of HI with associated FB injury and/or skull fracture. Injury groups were categorized and fatalities in each group were compared to understand differences between ED and HOSP.
For the subset of 1,145,575 patients with only HI, there were differences between HI of the deceased patients in ED and HOSP. The prevalence of deaths with FB injury was significantly higher in HOSP than ED ($P<0.0001$). When examining the prevalence of fatalities with skull fracture, the prevalence of skull fractures was significantly higher in HOSP versus ED ($P=0.0398$). For the population of patients that died with diagnosed FB injury, the prevalence without coexisting skull fracture was similar between ED and HOSP. However, the prevalence of ED deaths with diagnosed skull fractures without coexisting FB injury was greater than HOSP.
The differences between HI from the datasets may result from different objectives and treatment capabilities between the two departments. Due to the occult nature of FB injury and diagnostic tools needed to identify it, FB injury could be underdiagnosed; therefore underreported in the ED, especially in cases where brain injury is not associated with skull fractures. This study emphasizes that caution should be exercised when utilizing this dataset for HI analysis or fatality studies.

15. SUBJECT TERMS

National Trauma Databank, head injuries, emergency department, hospital inpatient records, RDS, Research Dataset

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1. Introduction

Head injuries are a common cause of traumatic deaths (Champion et al. 1990; Jennett 1996; Pickett et al. 2001; Schreiber et al. 2002; Langlois et al. 2006; Vakil and Singh 2017; Alao and Waseem 2020) via blunt or penetrating mechanisms. Different injury patterns of head injury are observed between blunt and penetrating mechanisms, where penetrating injuries tend to be more readily apparent and blunt injuries can be occult in nature. Common injuries involved in penetrating and blunt head trauma are skull fracture and focal brain injury. In general, focal brain injury is an occult head injury that requires advanced diagnostic tools such as computed tomography (CT) or magnetic resonance imaging (MRI) for identification of intracranial pathology (Pickett et al. 2001; Vakil and Singh 2017; Alao and Waseem 2020) where skull fractures may be more apparent.

Civilian health databases provide a convenient and accessible platform for tracking head injury mechanisms and patterns using large patient populations (Haider et al. 2012; Haider 2013). In particular, the National Trauma Data Bank (NTDB) is composed of over 700 national trauma hospitals that collect and organize patient information for analysis. NTDB collects information such as demographics, vital signs, transport mode and time, event mechanism, diagnosis, procedures, length of stay, facility, and departments visited. Utilization of this common civilian database provides a unique opportunity to investigate head injuries using a large national population that can be filtered by injury mechanism to explore the relationship between skull fracture and focal brain injury.

The original Head Injury Criterion (HIC) was developed as an injury metric for determining skull fracture but did not originally include brain injury (Lissner et al. 1960; Hess 1980). Skull fractures are more easily generated, observed, and measured in the laboratory compared to brain injury. For injury biomechanics studies, it is important to gain a better understanding of the relationship between skull fracture and brain injury, especially between different mechanisms such as blunt and penetrating. Among other things, these analyses are pertinent for automobile crash injury studies, motorcycle helmet investigations, and military protection evaluations. Since the original development of HIC, additional head injury criteria have been developed to include brain injuries (Takhounts et al. 2003; Marjoux et al. 2008; Kimpara and Iwamoto 2012; Takhounts et al. 2013). To gain a better understanding of the relationship between skull fracture and brain injury, NTDB was mined for head injury cases.

Due to the difficulty in diagnosing occult brain injuries without advanced diagnostic equipment, there may be caveats to using large civilian databases, such as NTDB, for head injury analysis. Trauma victims often first interact with the medical care system in the emergency department (ED). To treat patients who need continued and specialized care to recover, patients are normally admitted to the hospital. Because the NTDB captures and tracks patient data in the ED and hospital separately, potential differences in diagnoses and outcomes between the two patient populations can be explored. NTDB data has been used previously to analyze head injuries with success (Cook et al. 2011; Chen et al. 2012; Osler et al. 2016, Winkler et al. 2016; Haltmeier et al. 2017; Aiolfi et al. 2018; Dhillon et al. 2018); however, the specific differences between focal brain injury and skull fracture in the ED and hospital have yet to be documented. The objective of this research study was to investigate the prevalence of skull fracture and focal brain injury between ED and hospital inpatient records to identify if there was a bias in the types of head injury associated with fatalities using the NTDB.

2. Methods

A retrospective cohort design was used to conduct a study of head injury with associated focal brain injury and/or skull fracture. The cohort was defined as adults ages 17–55 years (chosen based on general age of comparable military group) with injuries to only the head as a result of either penetrating or blunt force trauma identified in the 2013–2015 NTDB Research Datasets (RDSs), provided by the American College of Surgeons. These years of NTDB data were chosen because they reported International Classification of Diseases, ninth revision (ICD-9 codes), whereas later years of NTDB switched to the tenth revision (ICD-10). Data was imported into JMP14 software (SAS, Cary, NC, USA) using a systematic approach where the ICD-9-CM codes and other pertinent information provided by NTDB were joined in the order of 1) external cause of injury codes (RDS_ECODES), 2) diagnosis codes (RDS_DCODES), 3) demographic information (RDS_DEMO), 4) emergency department information (RDS_ED), and 5) hospital stay information (RDS_DISCHARGE) matching each specific incident when joining. NTDB defines incidents as a single person and will be referred to as “patient” going forward. A filtering process with exclusion criteria based on demographic information, external cause of injury codes, relevant age, and Abbreviated Injury Scale (AIS) scores matched to ICD-9-CM diagnosis was implemented (Fig. 1). The total number of patients and their injury count was tabulated for each step using the unique patient code. Initially there were 2,607,945 patients in the dataset from 2013 to 2015. Patients with a lack of demographic information were excluded, and then the remaining were filtered through the external cause of injury mechanisms.

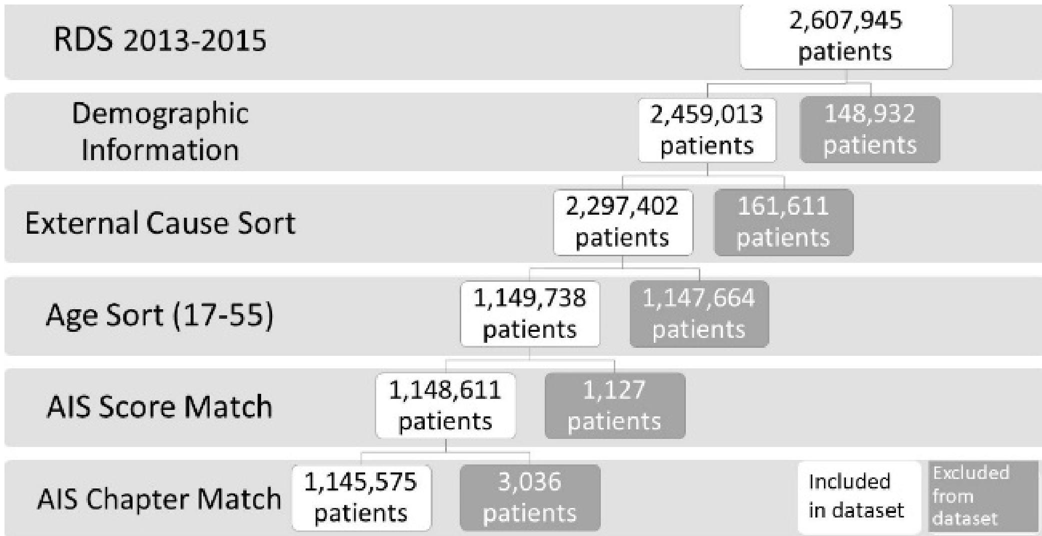

Fig. 1 Filtering process from RDS years 2013–2015 with patient population and total injury quantities for each step in the filtering process. Totals presented in the gray boxes indicate the data that was excluded from the dataset through each step in the process, while the white boxes represent the included data.

2.1 External Cause of Injury/Age Sorting

To evaluate injuries most relevant for our study, only external cause codes associated with penetrating or blunt force trauma were included. These injury mechanisms were identified by using ICD-9-CM external cause of injury codes E2-20 and E800-999 reported in NTDB. Excluded were adverse outcome due to accidental poisoning (E850–869), surgical complications (E870–879), fire and flames (E890–E899), natural and environmental factors (E900–908, except 908.1–908.3, 908.8, 909.2, 909.3), suffocation or submersion (E910–913), other accidents (E924–928), adverse effects (E930–949), suicide by other than physical trauma (E950–952, E953–954, E958.1–959), and other inflicted injurious events (E961–962, 968, 968.3, 972, 977, 979.3, 980–984, 988.1–988.4, 988.7). After external cause sorting of population, the dataset was then filtered by age, where all those who fell outside the ages of 17–55 were excluded.

2.2 Head Injury Population/AIS Sorting

The standard entry of injury codes into NTDB for years 2013–2015 was ICD-9-CM, but ICD-9-CM was not designed for trauma injury research and groups the head, face, and neck together. To isolate head injuries of interest (i.e., injuries to the brain, skull, or scalp), the ICD-9-CM codes were mapped to Abbreviated Injury Scale (AIS) chapters (Barnard et al. 2013; Loftis et al. 2016) using a protocol that was developed by certified coders of both ICD and AIS (Loftis et al. 2016).

Although the map is robust, there was no match in AIS for some ICD-9-CM codes. For example, codes that included multiple body regions or injuries within one code, such as fractures involving skull or face with other bones (804) had no equivalent AIS score. Therefore, incidents and injuries that did not match with any AIS codes or chapters were excluded from this analysis (Fig. 1). After mapping the injuries to AIS, it was possible to select only the injuries that were associated with the head (i.e., AIS Chapter 1).

The ICD-9-CM diagnosis codes (D code) were used to classify the specific head injuries in the patients. Using the D code descriptions for presence and type of skull fracture, the patient was categorized as either having or not having a skull fracture. Also, skull fracture was assumed for any ICD code that had an open brain injury, but skull fracture was not specifically described (i.e., 851.1, 851.3, 851.5, 851.7, 851.9, 852.1, 852.3, 852.5, 853.1, and 854.1). Similar to skull fracture, using the D code descriptions, patients were categorized as either having or not having a focal brain injury. For the purposes of this study, the definition of focal brain injury included the brain and surrounding internal soft tissue structures using D codes such as cerebral contusion, injury to cranial nerves, cerebellum/brain stem laceration, and subdural, subarachnoid, or extradural hemorrhages.

Any crush, unspecific blood vessel injury, superficial wound, skull fracture, or unspecified brain injury was not included in the focal brain injury category for this study. Concussion was also excluded because of the difficulties and inconsistencies with diagnosis. Because some of the head injury patients had both skull fracture and focal brain injury, each patient was then further separated by the groups described in Table 1 to elucidate possible trends within the head injury population and for a better understanding of coexisting injuries.

Table 1 Head injury group definitions

Group	Injury category
None	No skull fracture and no focal brain injury
SF	Skull fracture, no focal brain injury
FB injury	Focal brain injury, no skull fracture
Both	Skull fracture and focal brain injury

Patients were either admitted to the ED, hospital, or both. Death was used as a means to investigate the differences in patient outcomes between the ED and hospital. For the patients admitted to the emergency department, death was determined via the ED disposition code (deceased/expired). Other patients that were not recorded beyond the ED may have been successfully treated and discharged. All other ED patients continued on to hospital admission. For the patients admitted to the hospital, death was identified via the hospital disposition code (expired). For patients admitted to both, the hospital disposition was used for the outcome measure.

The relationship between focal brain injury, skull fracture, and death was investigated between ED and hospital inpatient records. Prevalence of each injury type was calculated by grouping those deaths associated with the injury (focal brain injury/skull fracture) in the numerator, and the total population of deceased head injury patients within the ED or hospital head injury patients in the denominator. Further dividing the injuries so all injury categories contained unique patients, prevalence of each exclusive injury group (Table 1) was calculated using the respective population of each head injury category. Fisher's exact test was used to distinguish differences (Fisher 1922), with a significance value of P<0.05, in each fatal head injury category between the ED and hospital.

3. Results

For the subset of 1,145,575 patients with only head injuries evaluated in NTDB 2013–2015, there were differences in the distribution of head injury types in the deceased patients between the ED and hospital (Table 2). The prevalence of deaths with a focal brain injury was significantly higher in the hospital deaths than in the ED deaths (93.8% vs. 63.4%, P<0.0001). When examining the prevalence of deaths with a skull fracture, there was a significant difference between the ED and the hospital (58.2% vs. 55.4%, P=0.0398), but not to the same level of significance as focal brain injury.

Table 2 Head injury deaths in the ED and hospital sorted by focal brain injury and skull fracture

		Total number of deaths		Total combined deaths
		ED	**Hospital**	
Focal brain injury	**No**	748	234	982
	Yes	1,293	3,527	4,820
	Total number of deaths	2,041	3,761	5,802
Skull fracture	**No**	911	1,573	2,484
	Yes	1,130	2,188	3,318
	Total number of deaths	2,041	3,761	5,802

Table 3 shows the distribution of the head injury population for the ED and hospital after separating the population into groups accounting for coexisting head injuries. The prevalence of deaths in the skull fracture population without a coexisting brain injury was significantly higher in the ED than in the hospital (29.5% vs. 4.8%, P<0.0001). On the other hand, the prevalence in the focal brain injury population that was diagnosed with a focal brain injury without a coexisting skull fracture was significantly higher in the hospital deaths than in the ED (38.4% vs. 40.9%, P<0.0001).

Table 3 Distribution of unique deaths in the ED and hospital by grouped head injury

Group	Total number of deaths		Total combined deaths
	ED	Hospital	
None	415	130	545
SF	333	104	437
FB injury	496	1,443	1,939
Both	797	2,084	2,881
Total number of deaths	2,041	3,761	

4. Discussion

We hypothesized that there would be a significant difference between diagnoses between fatal head injury patients in the ED and those admitted to the hospital, and set out to investigate this knowledge gap using the NTDB. According to the results of this study, the prevalence of focal brain injuries and skull fractures differed in the patients that died in the ED compared to the hospital. When examining all of the deaths associated with diagnosed focal brain injuries (isolated and coexisting), the prevalence of deaths that had a diagnosed focal brain injury was 63.4% in the ED and 93.8% in the hospital. The difference between the prevalence of deaths that had a skull fracture (isolated and coexisting) was also significant between the ED and hospital, 58.2% versus 55.4%, respectively. More skull fracture deaths were seen in the ED than hospital admissions, and more focal brain injury deaths were present in hospital admissions. It is possible that due to the occult nature of the focal brain injury and diagnostic tools needed to identify this injury that focal brain injuries are underdiagnosed, and consequently, underreported in the ED.

To further elucidate the differences in head injuries, we examined differences between fatalities with isolated skull fracture and fatalities with diagnosed skull fracture or focal brain injury. The prevalence of deaths with diagnosed skull fractures without a coexisting brain injury being far greater in the ED than in the hospital (29.5% vs. 4.8%, respectively) provides some evidence that this may be due to a lack of diagnostic information needed to identify coexisting focal brain injury in the ED. Other sources have shown that intracranial hematoma (defined as focal brain injury in this study) was seen in 75% of skull fracture cases (Jennett 1996). While there are many other types of brain injuries that may be diagnosed besides an intracranial hematoma, this example shows that brain injury and skull fracture are often likely coexisting with more prevalence than found in the ED in this study. Furthermore, the prevalence of deaths without any diagnosed skull fractures or focal brain injuries was significantly higher in the ED compared to the hospital (20.3% vs. 3.5%, respectively). Detailed examinations of the recorded medical procedures for these patients help support this theory in that only 4.8% of the patients that died in the ED with skull fractures and no coexisting brain injury had additional procedures that might uncover focal brain injuries, compared to 50% of the hospital patients.

The NTDB is a powerful resource for head injury analysis because of its large population of trauma patients; however, caution must be taken to understand how the data is collected to perform a valid analysis (Haider 2013). The injury mechanisms reported in the NTDB database may not adequately describe the specific injury mechanism for each recorded injury. For example, the general mechanism of a motor vehicle accident is categorized as blunt, but may contain penetrating injuries as well, such as piercing from shattered glass. Also, the data in the years of NTDB used in this study was coded with ICD-9-CM, a system originally intended for insurance classification purposes with limited specificity for trauma research. The accuracy of the ICD codes in NTDB may also be affected by incomplete medical diagnostics, varying levels of detail of reports used to assign the codes, familiarity of ICD coding system of hospital staff, or specific hospital policies. Additionally, the quality of patient tracking between transfers may affect the veracity of the data between healthcare facilities. In this study, 1,805 patients were directly admitted to the hospital without accompanying data in the ED dataset. This may be a result of a transfer or direct referral from another health agency, but it is possible that some of the patients may have been transferred from the ED and given a new ID, potentially being counted twice. Finally, NTDB does not capture deaths that occurred on scene, which account for two-thirds of the head injury population in the United States (Jennett 1996), therefore limiting the scope of the population in this study to people who get transported to the ED or hospital.

As previously stated, the ICD-9-CM codes in NTDB were mapped to AIS to better isolate the head injuries of interest. The AIS codes for the patients in the 2013 dataset were initially obtained from the AIS table purchased as a supplement to the RDS from the American College of Surgeons; however, some inconsistencies were found when checking the AIS descriptions in the AIS 2005 update 2008 dictionary (Gennarelli and Wodzin 2008) to the original patient data. For example, some patients were assigned whole region AIS codes, such as 100999.9 (died of head injury), that did not die. Several other injuries did not map appropriately with the AIS codes and the described injuries or types within the NTDB dataset. Because the procedure used to assign the AIS codes in the American College of Surgeons dataset is uncertain and contained these incongruities, the Association for the Advancement of Automotive Medicine AIS ICD Injury Severity Score (ISS) map was used. This conversion maintains the fidelity of the original dataset by only matching the ISS region, AIS chapter, and highest AIS severity specifically with the ICD-9-CM codes. This alleviates the mismatch of descriptors while maintaining the integrity of region-specific severity data. We understand that the data analyzed in this report was from older datasets, covering years 2013–2015, which were the last few years of ICD-9-CM coding; however, this was intentional as the newer years used ICD-10. While there is an ICD-10-AIS08 map, ICD-10 was greatly expanded from ICD-9, and converting and mapping would have complicated the analyses and likely would have manipulated the data to a degree that results would be questionable (Loftis et al. 2016).

The findings in this study are also limited by the selection criteria used to obtain the patient population analyzed. We selected an age range of 17–55 as a military-relevant age group; however, these are also the typical driving ages in United States. In a previous study, younger ages and older ages were more likely exposed to head injury by falling than motor vehicle accident (Jennett 1996). The patients in this study had only head injuries with no other coexisting injuries on other parts of the body. Even though this analysis does not capture all skull fracture and focal brain injuries within the NTDB, it does rule out the cause of death being attributed to another body region. Also, the researchers did not include concussion in their definition of focal brain injury. Other researchers have defined brain injury differently (Saatman et al. 2008), so the findings in this study may not be directly comparable to other studies.

Within this analysis using the NTDB, differences between the ED and hospital admissions for the prevalence of focal brain injury and skull fracture associated with death were explored. Limitations of the NTDB dataset for the specific research questions must be taken into consideration when designing injury analyses. Certain considerations about the fidelity and quality of data must be judged within each field of the data bank before a complete analysis should take place. In this study, it was identified that the diagnostic information within the ED data may not provide a true representation of head injuries, such as focal brain injury. Hospital admission data may provide a more detailed diagnosis to more accurately represent the prevalence of brain injuries reaching medical treatment after traumatic events when using the NTDB.

5. Conclusion

It is important to understand the limitations of the data within the NTDB for specific injury analysis. This study of head injuries highlighted differences between the ED and hospital datasets for prevalence of injuries associated with death, such as a significantly higher prevalence of focal brain injury within the hospital admissions dataset. Because of the occult nature of focal brain injury and the differences between the objectives and resources of the ED and hospital, it is likely that the hospital admission data provides a more complete dataset of diagnosed head injuries in patients while in the healthcare system.

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List of Symbols, Abbreviations, and Acronyms

AIS	Abbreviated Injury Scale
ARL	Army Research Laboratory
CT	computed tomography
DAC	Data & Analysis Center
DEVCOM	U.S. Army Combat Capabilities Development Command
ED	emergency department
FB	focal brain
HIC	Head Injury Criterion
ICD-9-CM	International Classification of Diseases, ninth revision
ISS	Injury Severity Score
MRI	magnetic resonance imaging
NTDB	National Trauma Data Bank
RDS	Research Dataset
SF	skull fracture

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