Published in final edited form as:

Injury. 2021 May ; 52(5): 1138–1144. doi:10.1016/j.injury.2021.01.042.

Predictors of Traumatic Brain Injury Morbidity and Mortality: Examination of data from the National Trauma Data Bank

Gabrielle F. Miller, PhD[a], **Jill Daugherty, PhD**[a], **Dana Waltzman, PhD**[a], **Kelly Sarmiento, MPH**[a]

[a]Division of Injury Prevention, National Center for Injury Prevention and Control, CDC, Atlanta GA;

Abstract

Background: There is evidence to suggest that traumatic brain injuries (TBI) are increasing in the United States. It is important to examine predictors of TBI outcomes to formulate better prevention and care strategies.

Research Design: National Trauma Data Bank (NTDB) data from 2016 were used to report the percentage of TBI by age, sex, race/ethnicity, health insurance status, intent/mechanism of injury, Glasgow Coma Scale (GCS), disposition at emergency department, and trauma center level. Logistic regression models were run to estimate the adjusted odds ratios of patient and facility characteristics on length of hospital stay and in-hospital mortality (analyzed in 2020).

Results: There were 236,873 patients with TBI in the NTDB in 2016. Most patients with a TBI were male, non-Hispanic white, and had sustained a TBI due to an unintentional injury. After adjusting for other factors, individuals age 0–17, those who self-pay, and those with intentional injuries had increased odds of a shorter hospital stay. Older individuals, non-Hispanic black or Hispanic patients, those who had sustained an intentional injury, and those who were not seen in a Level I trauma center had higher odds of mortality following their TBI.

Conclusions: Public health professionals' promotion of fall and other TBI prevention efforts and the development of strategies to improve access to Level I trauma centers, may decrease adverse TBI health outcomes. This may be especially important for older adults and other vulnerable populations.

Keywords

TBI; trauma; mortality; morbidity

INTRODUCTION

Traumatic brain injury (TBI) is caused by an external impact or force to the head or body or a penetrating injury. Among trauma-related injuries, TBIs are among the most common

Corresponding Author: Gabrielle F. Miller, Division of Injury Prevention, National Center for Injury Prevention and Control, CDC, 4770 Buford Highway NE, Mailstop S106-08, Atlanta, GA 30341, Phone: 770-488-5328 , Fax: 770-488-3551, ygm3@cdc.gov.

No conflicts of interest or financial disclosures were reported by the authors of this paper. No funding was provided.

causes of death and disability worldwide.[1] The severity of a TBI can be classified as mild, moderate, or severe.[2] Individuals with a mild TBI are commonly seen in the emergency department (ED) or primary care setting and are generally asymptomatic within 1 to 4 months.[3,4] Conversely, individuals with a moderate or severe TBI may be hospitalized and experience long-term or life-long symptoms.[5,6] Most epidemiological surveillance on TBI in the United States is conducted via administrative records collection in hospitals and EDs. For example, estimates from the Centers for Disease Control and Prevention (CDC) using administrative healthcare records showed increases in TBI-related ED visits, hospitalizations, and deaths between 2006 and 2014.[7]

While administrative records are a common method for capturing TBI-related prevalence estimates in the U.S., they do not always allow for the provision of detailed context regarding patient demographics, injury characteristics, location of injury occurrence, or facility details. Previous studies assessing predictors of TBI outcomes, are often conducted on small samples, within a single state, or do not examine a full slate of factors that affect one's outcome. However, these studies have provided preliminary evidence that age,[6,8] sex,[9,10] race/ethnicity,[11,12] health insurance status,[11,13] injury severity,[8,14] intent/mechanism of injury,[15,16] and trauma center level designation[17] may impact a person's post-injury recovery and outcomes.[8,11] For example, Selassie and colleagues examined inpatient care of patients with varying TBI severity and found inequalities related to hospital admission based on a patient's insurance status, race, and sex.[11] Selassie concluded that patients who were uninsured were less likely to be admitted to the hospital regardless of injury severity, after adjusting for demographics, clinical and hospital characteristics.[11]

To better understand predictors of TBI outcomes we examined data from the National Trauma Data Bank (NTDB). It is the country's largest repository of trauma data with a goal of providing the trauma community with accessible, consistent, and quality data. The purpose of this study was to assess the effect of age, sex, race/ethnicity, health insurance status, intent/mechanism of injury, and injury severity on TBI-related mortality rates and length of hospital stay using NTDB data. Differences in in-hospital mortality rates and length of hospital stay by level of trauma care received were also examined.

METHODS

This analysis used 2016 NTDB data, which included 765 hospitals and is the largest trauma registry database in the United States. NTDB consists of aggregated trauma data from participating trauma centers across the United States that voluntarily report patient and incident data to and is managed by the American College of Surgeons. NTDB data is a convenience sample with variability in reporting across state and geographic region, and in 2016 (the most recently available year at the time of analysis) contained data on over 960,000 cases. Patients with TBI were identified using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes, applying a standard approach based on a framework presented in 2016.[18] The specific codes[1] included were:

"Where "-" indicates any fourth, fifth, or sixth character. Seventh character of "A" or "B" for S02.0, S02.1-, S02.8, and S02.91. Seventh character of "A" for S04.02, S04.03-, S04.04-, S06-, and S07.1."

S02.0, S02.1, S02.8, S02.91, S04.02, S04.03-, S04.04-, S06-, and S07.1.[18] Information on patient age, sex, and race/ethnicity were extracted from the demographics file. Health insurance and length of stay (i.e., total length of hospital stay) were extracted from the discharge file. Trauma center level was extracted from the facility file and is based on state level designation where Level I is the highest level trauma center and Level IV is the lowest level trauma center in our data. Disposition at ED was obtained from the ED file. Glasgow Coma Score (GCS) was obtained from the vitals file to assess injury severity; the first recorded GCS was used to assess a patient's TBI severity level and was obtained from the emergency medical service (i.e., the field) or the ED, wherever it was first recorded. GCS (range 3 to 15) was divided into 3 groupings: 3–8 for severe TBI, 9–12 for moderate TBI, and 13–15 for mild TBI.[19] The intent and mechanism of the injury were categorized based on the CDC-recommended external cause of injury mortality matrix for ICD-10. Mechanism and intent were identified using ICD-10-CM codes, applying a standard approach for unintentional, intentional and undetermined injuries.[20] Unintentional injuries were broken down into 4 mechanisms: falls, motor vehicle crashes, struck by or against, and other. Intentional injuries were broken down into self-harm/suicide and assault. Outcomes consisted of in-hospital mortality (survived or died) and length of stay (<48 hours, between 48 hours and 7 days, and >7 days). Length of stay was defined to capture differences in moderate TBI and severe TBI using previously identified criteria.[21]

Descriptive statistics of sample characteristics (age, sex, race/ethnicity, health insurance status, intent/mechanism of injury, GCS, disposition at ED, and trauma center level) among patients with TBI in the NTDB sample were calculated and reported by length of stay and mortality. χ^2 tests were run to identify associations between patient or facility characteristics and outcomes. A multinomial logistic regression model, controlling for sample characteristics, was run to estimate the adjusted odds ratios (aOR) of patient and facility characteristic on the length of hospital stay comparing <48 hours and >7 days to the referent group of 48 hours-7 days hours. A logistic regression model, controlling for sample characteristics, was run to estimate the aOR of patient and facility characteristics on mortality. Missing data was not imputed; listwise deletion was used to produce the analytic sample (n=169,364). The number of missing responses ranged from 30 to 29,654 cases (0.01% to 12.5%). Listwise deletion resulted in 67,509 missing cases (28.5%). Stata Version 15 (Stata Corp LP, College State, TX) was used to conduct all statistical analyses in 2020.

RESULTS

There were 236,873 visits with TBI to participating trauma centers in 2016 (Table 1). A summary of patient demographics is provided in Table 1. Most patients with a TBI were admitted to a hospital (88.1%), had a GCS of 13–15 (77.9%), and were seen at a Level I trauma center (50.4%). Unintentional injury contributed to the majority of TBI-related visits (88.3%), with unintentional falls the leading mechanism of unintentional TBIs. Among patients whose TBI resulted from an intentional injury (10.5%), most were the result of an assault.

About 48% of patients with a TBI were hospitalized for less than 48 hours, 32.9% were hospitalized for 48 hours to7 days, and 19.5% were hospitalized for more than 7 days (Table

2). About 1.5% of patients with a TBI died. Length of hospital stay varied by age, sex, race/ethnicity, health insurance status, intent/mechanism of injury, injury severity, and trauma center level. For in-hospital mortality risk, age, sex, race/ethnicity, health insurance status, intent/mechanism of injury, and injury severity varied between the groups.

Individuals aged less than 75 years had higher odds (aOR = 1.25 – 3.96) of a shorter hospital stay (< 48 hours) than adults aged 75+ years, while controlling for other factors (i.e., sex, race/ethnicity, health insurance status, intent/mechanism of injury, trauma center level designation, GCS) (Table 3). Hispanic patients had lower odds (aOR = 0.88) of a shorter hospital stay than non-Hispanic white patients while non-Hispanic black patients had significantly higher odds (aOR = 1.04) of a shorter hospital stay than non-Hispanic white patients. Individuals who were self-pay (aOR = 1.27) had higher odds of a shorter hospital stay than individuals with private insurance. Female patients had lower odds (aOR = 0.79) of a longer hospital stay than male patients. Patients with Medicare (aOR = 0.83) and self-pay (aOR = 0.75) had lower odds and patients with Medicaid had higher odds (aOR = 1.09) of a longer hospital stay than patients with private insurance. Patients who sustained their TBIs through intentional injuries had lower odds (aOR = 0.60) of a longer hospital stay than patients with TBIs stemming from unintentional injuries.

When looking at the odds of death after TBI, patients aged less than 75 had lower odds (aOR=0.41–0.74) of dying as compared to patients aged 75+ years, while controlling for other factors. Non-Hispanic black patients (aOR = 1.48) and Hispanic patients (aOR = 1.19) had higher odds of dying compared to patients who were non-Hispanic white. Patients with Medicare (aOR = 0.73) and Medicaid (aOR = 0.69) had lower odds of death and patients who self-paid had greater odds (aOR = 2.59) of death than patients with private insurance. Patients who sustained their TBIs through intentional injuries had greater odds (aOR = 2.42) of dying than patients with TBIs from unintentional injuries. Individuals with a GCS of 13–15 had lower odds of dying than patients with a GCS of 3–8 (aOR = 286.69) or 9–12 (aOR = 7.86). Finally, patients seen at a Level I trauma center had decreased risk for mortality as compared to patients seen at lower level trauma centers: Levels II (aOR = 1.28), Level III (aOR = 1.54), and Level IV (aOR = 1.98).

DISCUSSION

This study provides insights into potential predictors of morbidity and in-hospital mortality among individuals with TBI seen in U.S. trauma centers reporting to the NTDB. Length of hospital stay and mortality risk were related to a patient's injury severity (i.e. GCS). However, length of hospital stay and mortality risk were also closely associated with a patient's age, sex, and injury intent. Moreover, disparities were observed by a patient's race/ethnicity and health insurance status; patients who identified as self-pay or who were non-Hispanic black were at increased risk for death following a TBI. These findings suggest there may be inequalities related to risk and treatment for adverse outcomes among these patients with TBI.

Most TBI-related visits were due to unintentional injuries, particularly falls, in this study. This generally mirrors findings of previous research conducted with the NTDB.[22,23]

However, it is important to note that there is a strong effect of age on primary mechanism of injury, as Dams-O'Connor and colleagues' analysis of 2007–2010 NTDB data makes clear.[24] Motor vehicle crashes are more likely to cause TBIs among younger individuals whereas unintentional falls are responsible for the majority of TBIs among middle age and older adults.[24] Previous nationally representative research in the U.S. reported that unintentional falls are responsible for a higher rate of TBI-related ED visits, hospitalizations, and deaths than any other mechanism of injury.[7] However, similar to what Dams-O'Connor et al. report,[24] the patterns do vary by age. For example, motor vehicle crashes contribute to a higher number and rate of TBI-related ED visits in the U.S. among those age 15–24 and 25–34 than other mechanisms of injury.[7] For every other age group, unintentional falls are the number one cause of TBI-related ED visits in the U.S.[7] While the majority of TBIs in our study were due to unintentional causes, it is important to note that those patients who sustained their TBI due to an intentional injury (e.g. assault) had a higher risk of mortality.

The finding that older adults were more likely to have longer hospital stays and a greater risk of dying following a TBI as compared to other age groups is supported in the U.S. literature.[24–27] Of concern, the rates of TBI-related ED visits, hospitalizations, and deaths among older adults (age 65 and older) have increased substantially over the last decade in the U.S.[7,25] Other high-income countries such as United Kingdom,[28] Netherlands,[29] and Australia[30] have also noted high and increasing rates of TBIs among older adults. As noted, falls pose the largest threat for sustaining a TBI among this age group.[25] There are several efforts underway to promote screening for older adults' fall risk during routine medical exams.[31] One such program developed by the Centers for Disease Control and Prevention (CDC) is called STEADI (Stopping Elderly Accidents, Deaths, & Injuries). It includes tools and resources for healthcare providers designed to decrease the risk for falls and mitigate the risk for injuries that may occur as a result.[32] However, there are currently no evidence-based clinical guidelines in the United States specific to the diagnosis and care of TBI among older adults. Given the unique needs of this vulnerable population, development of age-specific evidence-based clinical recommendations for diagnosis and care of TBI may be beneficial.

Length of hospital stay is a commonly used quality control measure in hospitals.[33,34] Longer time in the hospital can increase a patient's risk for infection and other adverse events.[35–37] Conversely, prematurely discharging a patient and shortening their time in the hospital may result in a patient not getting needed services or care, especially for patients with limited or no access to supportive or follow-up care.[38] The importance of effectively managing a patient's length of hospital stay is best exemplified by findings in our study related to a patient's health insurance status and race/ethnicity. Patients who identified as self-pay or as non-Hispanic black were more likely to stay <48 hours in the hospital. Self-pay or non-Hispanic black patients were also more likely to die in the hospital following a TBI. Other research has highlighted a similar finding that those who were self-pay had a higher percentage of stays with an in-hospital death.[39] Patients identified as self-pay are generally patients who do not have health insurance or have health insurance, but their insurer does not have a contract with the hospital where they are receiving care.[40] Research has suggested that hospitals in the U.S. may charge rates that are up to 2.5 times higher for self-pay patients than what most health insurers actually pay, which may contribute to the shorter hospital stays we found among this group.[40] Having private insurance in this and other studies was associated with lower mortality and improved clinical outcomes. Internationally, countries with universal healthcare coverage are less likely to find TBI treatment or outcomes disparities by insurance coverage or ability to pay. For example, all Canadian residents have free and equal access to inpatient TBI acute care and rehabilitation[41]

Furthermore, race/ethnicity is associated with access to TBI care, with non-Hispanic blacks and Hispanic patients less likely to receive intensive rehabilitation post-TBI as compared to non-Hispanic white patients with TBI.[42] While overcoming health inequalities in the U.S. is an ongoing challenge, targeted TBI prevention efforts and adaptation of evidence-based programs shown to be effective in reducing health disparities for other health conditions (e.g., care coordination, community outreach and partnerships, case management) for TBI patients may be helpful.[43]

While most findings in this paper highlighted potential risk factors for adverse outcomes in this study population, one finding related to trauma care designation pointed to improved patient outcomes. It is estimated that worldwide, 39% of people who sustain a severe TBI die due to their injury.[44] Both short- and longer-term outcomes are usually better in high-income countries such as the U.S. In lower income countries, many types of traumatic injuries are often treated by clinicians without proper training.[45] Patients in our study who received care at a Level I trauma center were more likely to survive following a TBI. This finding is consistent with previous studies of patients with TBI and other injuries.[46–48] However, access to Level I trauma centers varies substantially by state and even within a state in the United States.[49] Thus, a patient's place of residence may play a role in their survival and quality of life following a TBI.[50–52] Internationally, studies have suggested that individuals who sustain a TBI in rural areas generally have poorer outcomes than those who are injured in urban areas; this is particularly true in lower-income countries.[53,54] To address these disparities and improve survival rates for injured patients, the National Academies of Science called for the development of a national trauma care system that would improve care and access to trauma centers throughout the United States.[55] However, until such a system exists, experts suggest that greater awareness among affected communities, strategically locating medical helicopter bases, and establishing formal agreements for sharing trauma care resources across states may be beneficial.[49,56]

While NTDB provides a unique dataset from which to examine TBI with more information about the context of the injury than other datasets, there were several limitations to this study. First, NTDB is not a nationally representative database. Data from NTDB is a convenience sample obtained through voluntary participation from hospitals and there is substantial variation across states in the number and geographic distribution of trauma centers, as well as variation in reporting from existing trauma centers.[49,56] Similarly, individuals who were treated in other facilities, such as urgent care and community hospitals, were not reflected in the data. Therefore, these findings are generalizable only to TBI patients evaluated in hospitals with a trauma designation reporting to the NTDB, especially Level I and Level II trauma centers, and not to non-trauma hospitals. Data were not imputed where missing as previous research has suggested that imputation of NTDB data may lead to bias in the point estimates.[57] In this study, this resulted in 28.5% missing data. Additionally, the analytic sample was tested against the sample of missing data, and no variation in the outcome measures was found [data not shown]. Third, the models used in this analysis assume that all variables have an additive effect on the logistic scale. This is not intended to imply that the effect of a single variable has an identical effect on outcomes at all levels of every other variable. Rather, the purpose of the analysis was limited to assessing the mutually independent effects on outcomes and testing interaction effects was beyond the scope of the study. Fourth, trauma centers offer more extensive care than EDs and evidence suggests that the risk of death is significantly lower when care is provided in a trauma center than in a non-trauma center.[48] Thus, it is more likely that the types of injuries in NTDB are more severe than those captured in other databases. Fifth, this study did not comprehensively examine all predictors of TBI morbidity and mortality, for example socioeconomic status and distance of patient residence from hospital. Future studies may discover more predictors of TBI morbidity and mortality.

CONCLUSIONS

Findings from this study highlight risk factors that are associated with morbidity and mortality among patients with TBI seen in a sample of U.S. trauma centers. Public health professionals' promotion of fall and other TBI prevention efforts may decrease adverse TBI health outcomes, especially among older adults. Examples of such efforts include the expansion of evidence-based older fall prevention programs, such as CDC's STEADI, and the development of evidence-based clinical recommendations specific to older adults with TBI.

Acknowledgments

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

References

1. Rubiano AM, Carney N, Chesnut R, Puyana JC. Global neurotrauma research challenges and opportunities. Nature. 2015;527(7578):S193. [PubMed: 26580327]
2. Menon DK, Schwab K, Wright DW, Maas AI. Position statement: definition of traumatic brain injury. Arch Phys Med Rehabil. 2010;91(11):1637–40. [PubMed: 21044706]
3. Arbogast KB, Curry AE, Pfeiffer MR, et al. Point of health care entry for youth with concussion within a large pediatric care network. JAMA pediatrics. 2016;170(7):e160294. [PubMed: 27244368]
4. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Report to Congress on Mild Traumatic Brain Injury in the United States: Steps to Prevent a Serious Public Health Problem. Atlanta, GA: Centers for Disease Control and Prevention;2003.
5. Selassie AW, Zaloshnja E, Langlois JA, Miller T, Jones P, Steiner C. Incidence of long-term disability following traumatic brain injury hospitalization, United States, 2003. The Journal of head trauma rehabilitation. 2008;23(2):123–31. [PubMed: 18362766]
6. Corrigan JD, Cuthbert JP, Harrison-Felix C, et al. US population estimates of health and social outcomes 5 years after rehabilitation for traumatic brain injury. J Head Trauma Rehabil. 2014;29(6):E1–9.
7. Centers for Disease Control and Prevention. Surveillance Report of Traumatic Brain Injury-related Emergency Department Visits, Hospitalizations, and Deaths—United States, 2014. Atlanta, GA: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2019.

8. Whiteneck GG, Cuthbert JP, Corrigan JD, Bogner JA. Risk of Negative Outcomes After Traumatic Brain Injury: A Statewide Population-Based Survey. J Head Trauma Rehabil. 2016;31(1):E43–54.
9. Bai G, Bai L, Cao J, et al. Sex differences in cerebral perfusion changes after mild traumatic brain injury: Longitudinal investigation and correlation with outcome. Brain research. 2019;1708:93–9. [PubMed: 30553777]
10. Bazarian JJ, Blyth B, Mookerjee S, He H, McDermott MP. Sex differences in outcome after mild traumatic brain injury. J Neurotrauma. 2010;27(3):527–39. [PubMed: 19938945]
11. Selassie AW, Pickelsimer EE, Frazier L Jr, Ferguson PL. The effect of insurance status, race, and gender on ED disposition of persons with traumatic brain injury. The American journal of emergency medicine. 2004;22(6):465–73. [PubMed: 15520941]
12. Arango-Lasprilla JC, Kreutzer JS. Racial and ethnic disparities in functional, psychosocial, and neurobehavioral outcomes after brain injury. The Journal of head trauma rehabilitation. 2010;25(2):128–36. [PubMed: 20234227]
13. Alban RF, Berry C, Ley E, et al. Does health care insurance affect outcomes after traumatic brain injury? Analysis of the National Trauma Databank. The American surgeon. 2010;76(10):1108–11. [PubMed: 21105621]
14. Whiteneck GG, Cuthbert JP, Corrigan JD, Bogner JA. Prevalence of self-reported lifetime history of traumatic brain injury and associated disability: a statewide population-based survey. The Journal of head trauma rehabilitation. 2016;31(1):E55–62. [PubMed: 25931187]
15. McGarry LJ, Thompson D, Millham FH, et al. Outcomes and Costs of Acute Treatment of Traumatic Brain Injury. 2002;53(6):1152–59.
16. Shi J, Xiang H, Wheeler K, et al. Costs, mortality likelihood and outcomes of hospitalized US children with traumatic brain injuries. Brain injury. 2009;23(7–8):602–11. [PubMed: 19557562]
17. DuBose JJ, Browder T, Inaba K, Teixeira PGR, Chan LS, Demetriades D. Effect of Trauma Center Designation on Outcome in Patients With Severe Traumatic Brain Injury. Archives of Surgery. 2008;143(12):1213–7. [PubMed: 19075174]
18. Hedegaard H, Johnson R, Warner M, Chen L, Annest J. Proposed Framework for Presenting Injury Data Using the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) Diagnosis Codes. National health statistics reports. 2016(89):1–20.
19. Brennan PM, Murray GD, Teasdale GM. Simplifying the use of prognostic information in traumatic brain injury. Part 1: The GCS-Pupils score: an extended index of clinical severity. Journal of neurosurgery. 2018;128(6):1612–20. [PubMed: 29631516]
20. Hedegaard H, Johnson R, Garnett M, Thomas KE. The International Classification of Diseases, 10th Revision, Clinical Modification (ICD–10–CM) external cause-of-injury framework for categorizing mechanism and intent of injury. Hyattsville, MD: National Center for Health Statistics;2019.
21. Syed AT, Lone NA, Wani MA, Bhat AS. Clinical management of patients with minor head injuries. International journal of health sciences. 2007;1(1):131–40. [PubMed: 21475463]
22. Bonow RH, Quistberg A, Rivara FP, Vavilala MS. Intensive Care Unit Admission Patterns for Mild Traumatic Brain Injury in the USA. Neurocrit Care. 2019;30(1):157–70. [PubMed: 30136076]
23. Missios S, Bekelis K. The association of insurance status and race with the procedural volume of traumatic brain injury patients. Injury. 2016;47(1):154–59. [PubMed: 26187434]
24. Dams-O'Connor K, Cuthbert JP, Whyte J, Corrigan JD, Faul M, Harrison-Felix C. Traumatic brain injury among older adults at level I and II trauma centers. J Neurotrauma. 2013;30(24):2001–13. [PubMed: 23962046]
25. Taylor CA, Bell JM, Breiding MJ, Xu L. Traumatic Brain Injury-related Emergency Department Visits, Hospitalizations, and Deaths — United States, 2007 and 2013. MMWR: Morbidity and mortality weekly report. 2017;66(9):1–16. [PubMed: 28081055]
26. Giner J, Mesa Galan L, Yus Teruel S, et al. Traumatic brain injury in the new millennium: A new population and new management. Neurologia (Barcelona, Spain). 2019.
27. Flanagan SR, Hibbard MR, Riordan B, Gordon WA. Traumatic brain injury in the elderly: diagnostic and treatment challenges. Clinics in geriatric medicine. 2006;22(2):449–68. [PubMed: 16627088]

28. Hawley C, Sakr M, Scapinello S, Salvo J, Wrenn P. Traumatic brain injuries in older adults—6 years of data for one UK trauma centre: retrospective analysis of prospectively collected data. Emerg Med J. 2017;34(8):509–16. [PubMed: 28052919]
29. Scholten AC, Haagsma JA, Panneman MJ, Van Beeck EF, Polinder S. Traumatic brain injury in the Netherlands: incidence, costs and disability-adjusted life years. PLoS one. 2014;9(10):e110905. [PubMed: 25343447]
30. Harvey LA, Close JC. Traumatic brain injury in older adults: characteristics, causes and consequences. Injury. 2012;43(11):1821–6. [PubMed: 22884759]
31. Stevens JAB, Elizabeth R. A CDC Compendium of Effective Fall Interventions: What Works for Community-Dwelling Older Adults. Atlanta, GA: Centers for Disease Control and Prevention;2015.
32. Centers for Disease Control and Prevention. STEADI: Stopping Elderly Accidents, Deaths, & Injuries. 2019; https://www.cdc.gov/steadi/index.html. Accessed June 10, 2019.
33. American College of Surgeons. ACS Trauma Quality Improvement Program benchmark report: all patients, 2010 admissions. 2010; http://web4.facs.org/tqipfiles/ACS. Accessed January 31, 2020.
34. Agency for Healthcare Research and Quality. Examples of hospital quality measures for consumers. 2016; https://www.ahrq.gov/talkingquality/measures/setting/hospitals/examples.html. Accessed January 31, 2020.
35. Ingeman A, Andersen G, Hundborg HH, Svendsen ML, Johnsen SP. In-hospital medical complications, length of stay, and mortality among stroke unit patients. Stroke. 2011;42(11):3214–8. [PubMed: 21868737]
36. Mitchell BG, Ferguson JK, Anderson M, Sear J, Barnett A. Length of stay and mortality associated with healthcare-associated urinary tract infections: a multi-state model. The Journal of hospital infection. 2016;93(1):92–9. [PubMed: 26944900]
37. Al-Tawfiq JA, Tambyah PA. Healthcare associated infections (HAI) perspectives. Journal of infection and public health. 2014;7(4):339–44. [PubMed: 24861643]
38. Pickelsimer EE, Selassie AW, Sample PL, A WH, Gu JK, Veldheer LC. Unmet service needs of persons with traumatic brain injury. J Head Trauma Rehabil. 2007;22(1):1–13. [PubMed: 17235226]
39. Reid LD, Fingar KR. Inpatient Stays and Emergency Department Visits Involving Traumatic Brain Injury, 2017. Rockville, MD: Agency for Healthcare Research and Quality;2020.
40. Anderson GF. From 'soak the rich' to 'soak the poor': recent trends in hospital pricing. Health affairs (Project Hope). 2007;26(3):780–9. [PubMed: 17485757]
41. Cullen N Canadian Healthcare Perspective in Traumatic Brain Injury Rehabilitation. 2007;22(4):214–220.
42. Meagher AD, Beadles CA, Doorey J, Charles AG. Racial and ethnic disparities in discharge to rehabilitation following traumatic brain injury. Journal of neurosurgery. 2015;122(3):595–601. [PubMed: 25415069]
43. Penman-Aguilar A, Bouye K, Liburd LC, et al. Strategies for reducing health disparities—selected CDC-sponsored interventions, United States, 2016. 2014.
44. Rosenfeld JV, Maas AI, Bragge P, Morganti-Kossmann MC, Manley GT, Gruen RL. Early management of severe traumatic brain injury. The Lancet. 2012;380(9847):1088–98.
45. Johnson WD, Griswold DP. Traumatic brain injury: a global challenge. The Lancet Neurology. 2017;16(12):949–50. [PubMed: 29122521]
46. Adzemovic T, Murray T, Jenkins P, et al. Should they stay or should they go? Who benefits from interfacility transfer to a higher level trauma center following initial presentation at a lower level trauma center. J Trauma Acute Care Surg. 2019.
47. Sugerman DE, Xu L, Pearson WS, Faul M. Patients with severe traumatic brain injury transferred to a Level I or II trauma center: United States, 2007 to 2009. J Trauma Acute Care Surg. 2012;73(6):1491–9. [PubMed: 23188242]
48. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. The New England journal of medicine. 2006;354(4):366–78. [PubMed: 16436768]

49. Branas CC, MacKenzie EJ, Williams JC, et al. Access to trauma centers in the United States. JAMA. 2005;293(21):2626–33. [PubMed: 15928284]
50. Greene NH, Kernic MA, Vavilala MS, Rivara FP. Variation in pediatric traumatic brain injury outcomes in the United States. Archives of Physical Medicine & Rehabilitation. 2014;95(6):1148–55. [PubMed: 24631594]
51. Greene NH, Kernic MA, Vavilala MS, Rivara FP. Variation in Adult Traumatic Brain Injury Outcomes in the United States. J Head Trauma Rehabil. 2018;33(1):E1–8.
52. Coronado VG, Xu L, Basavaraju SV, et al. Surveillance for traumatic brain injury-related deaths: United States, 1997–2007. MMWR. 2011;60:1–32.
53. Maier D, Njoku I Jr, Schmutzhard E, et al. Traumatic brain injury in a rural and an urban Tanzanian hospital—a comparative, retrospective analysis based on computed tomography. World neurosurgery. 2014;81(3–4):478–82. [PubMed: 23954733]
54. Zhao M, Ya-Du, Wang M, Wenzhi Neurosurgical trauma in People's Republic of China. World journal of surgery. 2001;25(9):1202–4. [PubMed: 11571958]
55. Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector, Board on Health Sciences Policy, Board on the Health of Select Populations, Health and Medicine Division, National Academies of Sciences Engineering and Medicine. In: Berwick D, Downey A, Cornett E, eds. A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury. Washington (DC): National Academies Press (US); 2016.
56. Carr BG, Bowman AJ, Wolff CS, et al. Disparities in access to trauma care in the United States: A population-based analysis. Injury. 2017;48(2):332–8. [PubMed: 28069138]
57. Roudsari B, Field C, Caetano R. Clustered and missing data in the US National Trauma Data Bank: implications for analysis. Injury prevention. 2008;14(2):96–100. [PubMed: 18388229]

Table 1:

Demographics of patients with traumatic brain injury seen in United States trauma centers reporting to the National Trauma Data Bank, 2016

	n	%
Total TBI	236,873	
Age		
0–17	27,686	11.7
18–24	25,283	10.7
25–34	28,708	12.1
35–44	21,433	9.05
45–54	25,465	10.8
55–64	27,977	11.8
65–74	25,811	10.9
75+	39,140	16.5
Missing	15,370	6.49
Sex		
Male	151,453	63.9
Female	85,390	36.1
Missing	30	0.01
Race/ethnicity		
Non-Hispanic white	149,366	63.1
Non-Hispanic black	29,031	12.3
Non-Hispanic other	12,661	5.35
Hispanic	26,821	11.3
Missing	18,994	8.02
Health Insurance		
Private	82,101	34.7
Medicare	63,601	26.9
Medicaid	41,759	17.6
Other/other government	15,936	6.73
Self-pay	24,187	10.2
Missing	9,289	3.92
Intent/Mechanism of injury		
Unintentional injuries	**208,999**	**88.3**
Fall	104,811	44.3
Motor Vehicle	69,280	29.3
Struck by or Against	6,686	2.82
Other	28,222	11.9
Intentional Injuries	**25,148**	**10.6**
Self-harm	3,256	1.37
Assault	21,677	9.15
Legal/War	215	0.1

Author Manuscript

Author Manuscript

Author Manuscript

	n	%
Unknown/Undetermined Intent	**2,726**	**1.2**
Glasgow Coma Score (Injury Severity)		
3–8	32,214	13.6
9–12	10,712	4.52
13–15	184,395	77.9
Missing	9,552	4.03
Disposition at ED		
Discharged	17,977	7.59
Admitted to hospital	208,583	88.1
Died	3,602	1.52
Missing	5,252	2.22
Trauma Center Level		
Level 1	119,423	50.4
Level 2	71,529	30.2
Level 3	15,166	6.4
Level 4	1,101	0.5
Missing	29,654	12.5

Table 2:

Association of length of hospital stay and mortality by demographic, injury, and facility factors in individuals with traumatic brain injury seen in United States trauma centers reporting to - National Trauma Data Bank, 2016[a]

	Length of hospital stay			Mortality
	<48 hours N (%)	48 hours-7 days N (%)	>7 days N (%)	Yes N (%)
Total N (%)	112,784 (47.6)	77,885 (32.9)	46,204 (19.5)	3,602 (1.5)
Characteristic				
Age				
0–17	19,586 (70.7)	5,548 (20.0)	2,552 (9.2)	286 (1.0)
18–24	13,782 (54.5)	6,940 (27.5)	4,561 (18.0)	559 (2.2)
25–34	14,685 (51.2)	8,305 (28.9)	5,718 (19.9)	613 (2.1)
35–44	10,343 (48.3)	6,588 (30.7)	4,502 (21.0)	425 (2.0)
45–54	11,288 (44.3)	8,123 (31.9)	6,054 (23.8)	436 (1.7)
55–64	11,378 (40.7)	9,417 (33.7)	7,182 (25.7)	428 (1.5)
65–74	10,087 (39.1)	9,735 (37.7)	5,989 (23.2)	307 (1.2)
75+	13,944 (35.6)	17,343 (44.3)	7,853 (20.1)	413 (1.1)
p-value		<0.001		<0.001
Sex				
Male	72,421 (47.8)	47,167 (31.1)	31,865 (21.0)	2,630 (1.7)
Female	40,346 (47.3)	30,079 (36.0)	14,335 (16.8)	969 (1.1)
p-value		<0.001		<0.001
Race/ethnicity				
Non-Hispanic white	69,651 (46.6)	51,375 (34.4)	28,340 (19.0)	1,871 (1.3)
Non-Hispanic black	14,611 (50.3)	8,485 (29.2)	5,935 (20.4)	689 (2.4)
Non-Hispanic other	5,992 (47.3)	4,109 (32.5)	2,560 (20.2)	175 (1.4)
Hispanic	13,077 (48.8)	8,354 (31.2)	5,390 (20.1)	466 (1.7)
p-value		<0.001		<0.001
Health Insurance				
Private	41,703 (50.8)	24,431 (29.8)	15,967 (19.5)	977 (1.2)
Medicare	23,255 (36.6)	27,671 (43.5)	12,675 (19.9)	564 (0.9)
Medicaid	21,655 (51.9)	11,765 (28.2)	8,339 (20.0)	447 (1.1)
Other/other government	7,777 (48.8)	4,811 (30.2)	3,348 (21.0)	252 (1.6)
Self-pay	13,982 (57.8)	6,455 (26.7)	3,750 (15.5)	1,127 (4.7)
p-value		<0.001		<0.001
Intent/Mechanism of injury				
Unintentional injuries	**97,704 (46.8)**	**69,724 (33.4)**	**41,571 (19.9)**	**2,433 (1.2)**
Fall	47,740 (45.6)	39,444 (37.6)	17,627 (16.8)	439 (0.4)
Motor Vehicle Crashes	30,547 (44.1)	20,553 (29.7)	18,180 (26.20	1,589 (2.30
Struck by or Against	4,430 (66.3)	1,579 (23.6)	677 (10.1)	33 (0.5)
Other	14,987 (53.1)	8,148 (28.9)	5,087 (18.0)	372 (1.3)

Author Manuscript

Author Manuscript

Author Manuscript

	Length of hospital stay			Mortality
	<48 hours N (%)	48 hours-7 days N (%)	>7 days N (%)	Yes N (%)
Intentional Injuries	**13,771 (54.7)**	**7,399 (29.5)**	**3,978 (15.8)**	**1,082 (4.3)**
Self-harm	1,821 (55.9)	644 (19.8)	791 (24.3)	608 (18.7)
Assault	11,817 (54.5)	6,702 (30.9)	3,158 (14.6)	452 (2.1)
Unknown/Undetermined	**1,309 (48.0)**	**762 (28.0)**	**655 (24.0)**	**87 (3.2)**
p-value		<0.001		<0.001
Glasgow Coma Score (Injury Severity)				
3–8	12,210 (37.9)	6,534 (20.3)	(13,470) 41.8	3,338 (10.4)
9–12	3,131 (29.2)	3,394 (31.7)	4,187 (39.1)	46 (0.4)
13–15	92,842 (50.4)	64,768 (35.1)	26,785 (14.5)	86 (0.1)
p-value		<0.001		<0.001
Trauma Center Level				
Level 1	51,388 (43.0)	40,763 (34.1)	27,272 (22.8)	1.879 (1.6)
Level 2	33,846 (47.3)	24,777 (34.6)	12,906 (18.0)	1,145 (1.6)
Level 3	10,335 (68.2)	3,499 (23.1)	1,332 (8.8)	223 (1.5)
Level 4	827 (75.1)	178 (16.2)	96 (8.7)	18 (1.6)
p-value		<0.001		0.747

Note: Chi-square p-values are presented. Testing was done between unintentional, intentional, and unknown/undetermined intent.

[a]Row percentages are presented.

Table 3:

Association between length of hospital stay and mortality by selected characteristics in individuals with traumatic brain injury seen in trauma centers reporting to the National Trauma Data Bank, 2016

	Length of hospital stay		Mortality
	<48 hours	>7 days	
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Age			
0–17	3.96 (3.74–4.19) ***	0.69 (0.64–0.74) ***	0.47 (0.38–0.59) ***
18–24	2.04 (1.94–2.15) ***	0.95 (0.86–1.01)	0.42 (0.34–0.51) ***
25–34	1.81 (1.72–1.90) ***	1.05 (0.99–1.12)	0.41 (0.34–0.50) ***
35–44	1.61 (1.53–1.70) ***	1.08 (1.01–1.15) *	0.43 (0.35–0.52) ***
45–54	1.47 (1.40–1.54) ***	1.21 (1.14–1.29) ***	0.47 (0.38–0.57) ***
55–64	1.31 (1.25–1.37) ***	1.32 (1.25–1.40) ***	0.55 (0.46–0.67) ***
65–74	1.25 (1.20–1.30) ***	1.25 (1.19–1.31) ***	0.74 (0.61–0.89) ***
75+	Referent	Referent	Referent
Sex			
Male	Referent	Referent	Referent
Female	0.99 (0.97–1.01)	0.79 (0.77–0.82) ***	1.02 (0.92–1.12)
Race/ethnicity			
Non-Hispanic white	Referent	Referent	Referent
Non-Hispanic black	1.04 (1.01–1.08) *	1.17 (1.13–1.23) ***	1.48 (1.32–1.66) ***
Non-Hispanic other	0.94 (0.90–0.99) *	1.06 (1.00–1.13) *	0.95 (0.79–1.14)
Hispanic	0.88 (0.85–0.91) ***	1.08 (1.03–1.13) ***	1.19 (1.06–1.35) **
Health Insurance			
Private	Referent	Referent	Referent
Medicare	0.79 (0.76–0.82) ***	0.83 (0.79–0.87) ***	0.73 (0.62–0.86) ***
Medicaid	0.88 (0.85–0.91) ***	1.09 (1.04–1.13) ***	0.69 (0.60–0.79) ***
Other/other government	1.03 (0.98–1.07)	0.98 (0.92–1.03)	1.03 (0.86–1.22)
Self-pay	1.27 (1.22–1.32) ***	0.75 (0.71–0.79) ***	2.59 (2.32–2.89) ***
Intent/Mechanism of injury			
Unintentional injuries	Referent	Referent	Referent
Intentional Injuries	1.24 (1.19–1.29) ***	0.60 (0.57–0.63) ***	2.42 (2.19–2.67) ***
Unknown/Undetermined Intent	0.98 (0.88–1.09)	0.96 (0.85–1.09)	1.25 (0.93–1.67)
Glasgow Coma Score (Injury Severity)			
3–8	1.16 (1.12–1.20) ***	4.96 (4.78–5.16) ***	286.69 (218.12–376.82) ***
9–12	0.59 (0.56–0.63) ***	3.01 (2.85–3.18) ***	7.86 (4.89–12.66) ***
13–15	Referent	Referent	Referent
Trauma Center Level			
Level 1	Referent	Referent	Referent

	Length of hospital stay		Mortality
	<48 hours	>7 days	
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Level 2	1.17 (1.14–1.20) ***	0.82 (0.80–0.85) ***	1.28 (1.17–1.40) ***
Level 3	2.56 (2.44–2.69 ***	0.66 (0.62–0.71) ***	1.54 (1.28–1.84) ***
Level 4	4.64 (3.82–5.62) ***	0.70 (0.51–0.97) *	1.98 (1.08–3.61) *

Abbreviations: CI = confidence interval; AOR = adjusted odds ratio.

Note: Asterisk (*), double asterisk (**), triple asterisk (***) denote $p<0.05$, $p<0.01$ and $p<0.001$ significance level, respectively. Length of hospital stay was estimated using a multinominal logistic with the category 48 hours −7 days as a referent. Mortality was estimated using a logistic regression.