WestVirginiaUniversity
THE RESEARCH REPOSITORY @ WVU

Clinical and Translational Science Institute | Centers

11-1-2017

Treatment Charges for Traumatic Brain Injury Among Older Adults at a Trauma Center

Jennifer S. Albrecht
University of Maryland

Julia F. Slejko
University of Maryland

Deborah M. Stein
University of Maryland

Gordon S. Smith
University of Maryland

Follow this and additional works at: https://researchrepository.wvu.edu/ctsi

Part of the Medicine and Health Sciences Commons

Digital Commons Citation

Albrecht, Jennifer S.; Slejko, Julia F.; Stein, Deborah M.; and Smith, Gordon S., "Treatment Charges for Traumatic Brain Injury Among Older Adults at a Trauma Center" (2017). *Clinical and Translational Science Institute*. 654.
https://researchrepository.wvu.edu/ctsi/654

This Article is brought to you for free and open access by the Centers at The Research Repository @ WVU. It has been accepted for inclusion in Clinical and Translational Science Institute by an authorized administrator of The Research Repository @ WVU. For more information, please contact ian.harmon@mail.wvu.edu.

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

HHS Public Access
Author manuscript
J Head Trauma Rehabil. Author manuscript; available in PMC 2018 November 01.

Published in final edited form as:
J Head Trauma Rehabil. 2017 ; 32(6): E45–E53. doi:10.1097/HTR.0000000000000297.

Treatment Charges for Traumatic Brain Injury among Older Adults at a Trauma Center

Jennifer S. Albrecht, PhD[1], **Julia F. Slejko, PhD**[2], **Deborah M. Stein, MD, MPH**[3], and **Gordon S. Smith, MB, ChB, MPH**[1,4]

[1]Department of Epidemiology and Public Health, University of Maryland School of Medicine

[2]Department of Pharmaceutical Health Services Research, University of Maryland School of Pharmacy

[3]Department of Surgery, Division of Surgical Critical Care, R Adams Cowley Shock Trauma Center, University of Maryland Medical Center

[4]Shock, Trauma and Anesthesiology Research (STAR) – Organized Research Center, National Study Center for Trauma and Emergency Medical Services, University of Maryland, Baltimore

Abstract

Objective—To provide charge estimates of treatment for traumatic brain injury (TBI), including both hospital and physician charges, among adults aged 65 and older treated at a trauma center.

Methods—We identified older adults treated for TBI during 2008–2012 (n=1,843) at Maryland's Primary Adult Resource Center and obtained hospital and physician charges separately. Analyses were stratified by sex and all charges were inflated to 2012 dollars. Total TBI charges were modeled as a function of covariates using a generalized linear model.

Results—Women comprised 48% of the sample. The mean unadjusted total TBI hospitalization charges for adults aged 65 and older was $36,075 (standard deviation (SD) $63,073). Physician charges comprised 15% of total charges. Adjusted mean charges were lower in women than in men (adjusted difference −$894; 95% confidence interval (CI) −$277, −$1,512). Length of hospital and ICU stay were associated with the highest charges.

Conclusions—This study provides the first estimates of hospital and physician charges associated with hospitalization for TBI among older adults at a trauma center that will aid in resource allocation, triage decisions, and healthcare policy.

Keywords

Traumatic Brain Injury; Costs; Trauma Center; Older Adults

Corresponding Author: Department of Epidemiology and Public Health, University of Maryland School of Medicine, MSTF 334C, 10 S. Pine St., Baltimore, MD 21201, Phone: 410-706-0071, jalbrecht@epi.umaryland.edu.

The authors declare no conflicts of interest.

Author Disclosure Statement
No competing financial interests exist.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Introduction

Traumatic brain injury (TBI) is an important and growing health problem among older adults that results in more than 142,000 emergency department visits and 81,500 hospitalizations annually in the United States.[1] According to the US Centers for Disease Control and Prevention (CDC), rates of TBI-related emergency department visits among adults aged 65 and older increased steadily from 3.7/1,000 in 2001 to 6.0/1,000 in 2010 and TBI-related hospitalizations increased from 1.9/1,000 to 2.9/1,000 during the same period.[2]

In the US, the total lifetime cost of treatment for all injuries in 2000 was estimated at $406 billion, including $326 billion in lost productivity.[3] In the same year, costs for non-fatal fall-related injuries among older adults reached $19 billion.[4] Yet despite high hospitalization rates for TBI, there is limited information on costs among older adults, particularly those treated at trauma centers. Trauma center care is more expensive compared to a non-trauma center (mean adjusted costs in 2005 dollars $47,933 vs. $27,986), but these estimates aren't specific to TBI or older adults.[5] Older TBI patients historically are less likely to be triaged to a trauma center; however, that is changing due recognition of under triage of injuries in older adults and triage guidelines published by the CDC and the Eastern Association for the Surgery of Trauma.[6–10] Assessment of the costs of these encounters is therefore needed to guide hospitals, policymakers, and payers and to understand the implications of these changes.

The most recent estimates of TBI hospitalization charges are more than ten years old and come from studies conducted by Thompson et al. (2012) and Farhad et al. (2013), before the triage guidelines for older adult trauma were published.[11,12] Using data from the National Study on the Costs and Outcomes of Trauma 2001–2002, Thompson and colleagues calculated mean adjusted hospitalization costs for TBI among adults aged 65–74 ($25,482) and aged >74 ($18,829).[11] More recently, Farhad et al. (2013) analyzed data from the 2006–2007 Nationwide Inpatient Survey database and reported unadjusted mean hospitalization costs for TBI of $21,460.[12] Neither study stratified costs of TBI treatment by treatment location, i.e. trauma center vs. non-trauma center, and importantly, the Farhad study did not include physician charge data.[12]. In fact, physician charge data are not included on the hospital bill which is used in most cost studies. Physician services are always billed separately and are often difficult to obtain because of multiple providers without a central billing office. Consequently, physician costs are not usually included in studies on cost of injury, although prior estimates suggest they account for 18%–26% of total treatment costs for all-cause hospitalizations.[13] Even the comprehensive Thompson study did not break out separately the physician costs.[11] The objective of this study is to provide cost estimates of treatment for TBI, including both hospital and physician charges, among older adults treated at a Level 1+ trauma center using data from 2008–2012.

Methods

Data Sources

We analyzed hospitalization and physician charges among adults aged 65 and older who were treated for TBI at the R Adams Cowley Shock Trauma Center (STC) of the University

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

of Maryland Medical Center during 2008–2012. The STC is Maryland's Primary Adult Resource Center and is the busiest civilian trauma program in the United States, treating more than 8,000 patients annually including 33% of all trauma cases in Maryland.[14] Clinical, demographic, and injury characteristics were obtained from the STC trauma registry (STR). The STR is an administrative dataset used for quality assurance and contains data on all STC admissions since 1996. Thus, consent is not required and it is available for research following Institutional Review Board (IRB) approval. Hospital charge data were obtained from the finance department at the University of Maryland Medical Center. Physician charge data were obtained separately from the billing departments of the STC and University Faculty Physicians.

Study Participants

There are different age cut-offs for defining geriatric trauma. For our analysis we choose Medicare eligibility as a cut-point.[9,10] Therefore, all STC admissions during 2008–2012 aged 65 and older with a diagnosis of TBI (International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM)) codes 800.xx, 801.xx, 803.xx, 804.xx, 850.xx–854.1x, 950.1–950.3, 959.01) were eligible for this study. The CDC recommends these ICD-9-CM codes, plus an additional code for shaken infant syndrome (995.55) that we did not include, for TBI surveillance, and they have been reported to have a sensitivity of 89% to detect severe TBI and a positive predictive value of 93%.[15–17] To increase the specificity of the ICD-9 codes for TBI, we also required an Abbreviated Injury Scale (AIS) (version 1990) head score >0.[18]

Measures

We used the AIS head score to measure TBI severity and AIS scores from other body regions to calculate the Injury Severity Score (ISS), a measure of overall bodily injury.[19] The AIS system (1990) is used by trained coders to code injuries in the STR using evidence from CT and MRI scans and injury mechanisms are coded using ICD-9 external cause (E) codes. AIS is a method of ranking anatomic injury severity relative to its threat to life and ranges from 0–6, with lower scores indicating milder injury.[18] We specified seven AIS body regions: head, neck, face, thorax, abdomen, upper extremities, and lower extremities. We created an indicator variable measuring severity of injury to any another body region based on AIS score. We categorized this variable as no other injury (AIS score = 0), minor injury (AIS scores of 1–2), and moderate/severe injury (AIS scores ≥3).

The ISS is widely used to assign an overall severity score for patients with multiple injuries.[19] It is created by summing the squares of the three highest AIS codes in different body regions and ranges from 0 to 75. Although the AIS ranges from 0–6, a score of 6, currently unsurvivable, automatically sets the ISS at 75. To avoid collinearity, we created an amended version of the ISS for body regions other than head by subtracting the square of the head AIS score. This measure ranged from 0 to 66 and was dichotomized at <9 based on its distribution. The Glasgow Coma Scale (GCS) measures neurologic deficit in eye opening, verbal, and motor response.[20] It is commonly used as an initial measure of TBI severity because of its ease of administration.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Information on comorbid conditions was obtained during the STC admission assessment from personal medical history or proxy report and was coded using ICD-9-CM codes. We created the following indicator variables: alcohol dependence, Alzheimer's disease and related dementias, cardiac arrhythmia, chronic obstructive pulmonary disease (COPD), diabetes, depression, hypertension, heart failure, ischemic heart disease, neurologic disorders (includes Parkinson's disease and epilepsy), and stroke. Length of stay at STC was measured in days. Lengths of STC stay were categorized based on distribution as < 1 day, 1 to < 2 days, 2 to < 4 days, 4 to < 6 days, 6 to < 14 days, 14 to < 28 days, and ≥28 days. Length of intensive care unit (ICU) stay was categorized based on distribution as no ICU stay, < 2 days, 2 to < 6 days, 6 to < 12 days, and ≥ 12 days. Insurance information is collected on all admissions to STC. We created 3 categories of primary payer: 1) Medicare, including fee for service and Medicare Advantage; 2) auto insurance; and 3) other. The other category comprised self-pay, private commercial insurance, military or Veteran's Administration, and traveler's insurance.

Data Analysis

We examined distributions of all variables. Demographic and clinical characteristics differed significantly by sex therefore we stratified the univariate analyses. To gain an understanding of factors associated with increased charges and identify covariates for our adjusted model, we conducted multiple stratified analyses of mean unadjusted TBI hospitalization charges, physician charges, and total charges. Charges were inflated to 2012 dollars using the consumer price index.

During univariate analysis we observed that some individuals had significantly elevated total TBI charges. To better understand characteristics associated with very high charges, we conducted a sub-analysis of individuals comprising the top 1% of total hospitalization charges (≥ $289,000).

Total TBI charges were modeled as a function of covariates using a generalized linear model (GLM). We selected the appropriate distribution family using the Modified Park and the Reset test and selected the appropriate link function using the Pearson Correlation Test, Pregibon Link Test, and the Modified Hosmer and Lemeshow test (for specification). Covariates were selected into our final model based on a p-value of <0.05 in bivariate analysis, a p-value of <0.05 using likelihood ratio statistics from the GLM, and evidence of model fit from Likelihood and deviance statistics. Our final model used a gamma distribution and identity link to model mean total charges as a function of sex, AIS head score, the dichotomized amended Injury Severity Score (ISS), length of ICU stay, length of hospital stay, and in-hospital mortality. We calculated adjusted mean charges, marginal effects and 95% confidence intervals using the delta method.

Data analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC) and STATA Release 14 (StataCorp. 2015. College Station, TX), and a p-value of < 0.05 was considered statistically significant. This study was approved by the IRB of the University of Maryland, Baltimore.

Author Manuscript

Results

There were 2,030 adults aged 65 and older treated at the STC for TBI during 2008–2012. Of these, 1,843 (91%) had complete physician and hospital charge data and were included in this study. Individuals without complete charge data (n=187) did not differ significantly by age, sex, or injury characteristics from those with complete charge data. However, individuals without complete charge data were more likely to have a head AIS score of 1 vs. AIS 2–6 (26% vs 20%, p=0.04), to have been transported to the STC directly from the injury scene (73% vs. 54%, p<0.001), and to be admitted in 2008 (47% vs. 15%, p<0.001) compared to those who had complete charge data.

Demographic and clinical characteristics of the sample, stratified by sex, are listed in Tables 1 and 2. Women comprised 48% of the sample and were older, with average age 79.9 (standard deviation (SD) 8.2) years compared to 76.8 (SD 7.7) years for men (p<0.001). Women were more likely than men to have Medicare coverage (85% vs. 78%, p<0.001). Average length of hospital stay among women was shorter (p<0.001) and women were more likely not to have an ICU stay (73% vs. 65%, p<0.001). Women were also less likely to be dead at discharge from the STR (14% vs. 18%, p=0.008). Based on an admission GCS score of 14 or 15, 73% of the sample had mild TBI. Distribution of the AIS head score differed by sex, with women less likely to have a score of ≥5 compared to men (17% vs. 22%, p=0.02). Women were more likely to have been injured in a fall (83% vs. 72%, p<0.001) compared to men.

Mean unadjusted hospitalization, physician, and total charges are presented in Table 3. Mean unadjusted total TBI hospitalization charges for adults aged 65 and older were $36,075 (SD $63,073). Charges for women were lower than for men ($27,797 (SD $45,404) vs. $43,673 (SD $74,971), Student's t-test p<0.001). Hospital charges ($30,651 (SD $53,702) comprised 85% of the total charges and physician charges ($5,425 (SD $10,895)) made up the remaining 15%. Charges varied greatly by sex, injury severity, payer, and vital status at discharge, but the primary drivers of unadjusted charges were ICU stay and length of hospital stay.

Adjusted mean charges were lower in women than in men (adjusted difference −$894; 95% confidence interval (CI) −$277, −1,512)(Table 4). Length of hospital stay and ICU stay had the largest impact on adjusted mean total TBI hospitalization charges. Charges increased exponentially compared to a length of stay of <1 day, with adjusted differences of $1,986 (95% CI $1,103, $2,870) for individuals with a length of stay of 1 to <2 days up to $236,657 (95% CI $169,242, $303,272) for individuals with a stay of ≥28 days. Similarly, individuals with an ICU stay of < 2 days had adjusted charges of $3,010 (95% CI $1,032, $4,989) more than those with no ICU stay while those with an ICU stay of ≥12 days had an adjusted difference of $70,247 (95% CI $43,779, $96,716). Only the most severe TBI (AIS ≥5) was a significant predictor of increased adjusted mean charges when compared to AIS 1 (adjusted difference $1,593 (95% CI $103, $3,083).

Our sub-analysis of individuals comprising the top 1% of total charges (n=19) revealed that they were more likely to be men (74% vs. 52%, p=0.06) and to have other insurance, which includes no insurance (26% vs. 9%, p=0.03). They had more severe TBI as evidenced by a head AIS score of 5 or more (42% vs. 20%, p=0.04) and more severe overall injury, measured as an ISS ≥9 (58% vs. 26%, p=0.002). They were more likely to have an ICU stay ≥12 days (89% vs 7%, p<0.001), an overall hospital stay ≥28 days (89% vs 1%, p<0.001), and to be discharged to a rehabilitation facility (100% vs. 55%, p=0.02). Individuals with the highest charges were more likely to have been injured in a motor vehicle collision (53% vs. 17%, p<0.001). In terms of injury location, these individuals were more likely to have injuries to the spine (47% vs. 19%, p=0.002) and abdomen (37% vs. 11%, p<0.001). Finally, the mean unadjusted total charges for these individuals was $427,080 (SD $143,960).

Discussion

Older adults are the only age group for whom hospitalization rates for TBI are increasing and the costs are significant.[2] Mean charges for TBI hospitalization at a Level 1 trauma center totaled $36,075 for adults aged 65 and older and were significantly higher among men compared to women. Physician charges comprised 15% of total charges. Length of hospital and ICU stay were associated with the highest charges, even when controlling for TBI and other injury severity.

Prior cost estimates of TBI hospitalization from other studies ranged from $18,829 to $28,566, but these estimates are over ten years old, included mixed ages and treatment locations, and did not specifically break out physician charges.[11,12,20] In fact, the Farhad and Schootman studies did not include physician charges and therefore likely underestimated total costs.[12,21] These prior studies used cost-to-charge ratios available for their data to calculate the resource cost of treatment from billed charges, which may explain some of the variation between prior estimates and our own.[22,23]

The average cost-to-charge ratio for urban hospitals in Maryland in 2012 was 140.65%.[24] Applying this ratio to our mean unadjusted charges results in a cost estimate of $25,649. Compared to Thompson's cost estimate of $25,482, our calculated estimate suggests that the cost of treating older adults for TBI at a trauma center has not increased significantly over the last decade. Although this seems counterintuitive, it is possible that the rapid availability of computed tomography scans and trauma surgeons at a trauma center may reduce the need for unnecessary hospitalizations, result in reduced length of hospital stay, or that modern triage guidelines are resulting in less severe cases coming to trauma centers to rule out more serious injuries. In addition as Maryland has one of the lowest cost-to-charge ratios in the United States due to highly regulated rate setting by the Maryland Health Services Cost Review Commission, our costs could be lower than the national average.[25]

Mechanism of injury may also contribute to differences in cost. Hospital charges for TBI sustained in a motor vehicle collision in Ohio averaged $46,441 while Farhad et al. reported mean cost for treatment of TBI, regardless of mechanism ($21,460), from the same timeframe.[12,26] This variation is partially attributable to reporting of charges in the Ohio study vs. costs in the Farhad study but also suggests that mechanism of injury may impacts costs. This is consistent with our sub-analysis restricting to those with the top 1% of costs where motor vehicle collisions accounted for a larger percentage of injuries as well as prior

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

reports and provides a rationale for lower TBI treatment costs among older adults as well as our observation that charges for older women, who are even less likely to be injured in a motor vehicle collision, are significantly less than charges for older men.[11,27–29] While there are no national cost estimates for treatment at a trauma center that are specific to TBI, in 2005 the average cost of hospitalization at a trauma center for individuals with any injury receiving a minimum AIS score of 3 was $47,933.[5] This estimate is inflated by the higher hospitalization costs for younger adults and exclusion of milder (AIS <3) injuries, and consequently is difficult to compare to our findings.[5,11,12]

Length of hospital and ICU stay were the primary drivers of adjusted charges in this study. In particular, a hospital stay of 4–6 days doubled the total adjusted hospitalization charges compared to a stay of <1 day, while staying 14–27 days resulted in a five-fold increase in charges. Prior studies on TBI costs did not examine ICU or length of stay but identified other characteristics associated with increased costs such as TBI and overall injury severity, consistent with our findings.[26,30,31] Unadjusted mean charges for older women were significantly lower than those of older men, consistent with prior literature in mixed age groups and likely resulting from shorter average length of hospital stay and less time in the ICU, perhaps due to differences in injury mechansim.[12] Once adjusted for factors associated with increased charges, the difference between men and women was reduced to a minimal but statistically significant $894.

A limitation of this study and many others is its focus on charges instead of actual costs. Charge information represents the amount that hospitals and physicians billed for services, but does not reflect the specific amounts that hospitals received in payment, which could be significantly lower, or the actual resource cost to hospitals. This study was conducted at a single urban trauma center in Maryland; hence results may not be generalizable to all trauma centers where TBI is treated. Finally, costs of rehabilitation post-discharge were not included in this study, yet they significantly increase costs of treatment. In our sub-analysis of individuals with the highest charges, those who survived (13/19 = 68%) were discharged to a rehabilitation facility where they would incur more costs. In a prior study, the index hospitalization event accounted for only 31% of total 1-year TBI-related costs among individuals aged 65–74, and 24% of total 1-year costs among individuals aged 75 and older.[11] In our study, 33% of those treated were discharged home with the remainder discharged to another billable location such as for skilled nursing or rehabilitation.

This study provides estimates of the hospital and physician charges associated with hospitalization for TBI among older adults at a Level 1+ trauma center that will aid in resource allocation, triage decisions, and healthcare policy.

Acknowledgments

Dr. Albrecht was supported by National Institutes of Health grant K12HD43489-13 and Agency for Healthcare Quality and Research grant 1K01HS024560. Dr. Smith was supported by U.S. National Institute on Alcohol Abuse and Alcoholism grant R01AA18707.

Thanks to Dr. Eberechukwu Onukwugha for statistical guidance.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

References

1. Faul, M., Xu, L., Wald, MM., et al. Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths, 2002–2006. Atlanta, Georgia: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010. Available at: http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf [Accessed 3/2/16]
2. Centers for Disease Control and Prevention. [Accessed 4/13/16] Rates of TBI-related hospitalizations by age group – United States, 2001–2010. Available at: http://www.cdc.gov/traumaticbraininjury/data/rates_hosp_byage.html
3. Corso P, Finkelstein E, Miller T, Fiebelkorn I, Zaloshnja E. Incidence and lifetime costs of injuries in the United States. Injury Prevention. 2006; 12:212–218. [PubMed: 16887941]
4. Stevens JA, Corso PS, Finkelstein EA, Miller TR. The costs of fatal and non-fatal falls among older adults. Injury Prevention. 2006; 12:290–295. [PubMed: 17018668]
5. MacKenzie EJ, Weir S, Rivara FP, Jurkovich GJ, Nathens AB, Wang W, Scharfstein DO, Salkever DS. The value of trauma center care. J Trauma. 2010; 69:1–10. [PubMed: 20622572]
6. Kodadek LM, Selvarajah S, Velopulos CG, Haut ER, Haider AH. Undertriage of older trauma patients: is this a national phenomenon? J Surg Res. 2015; 199(1):220–229. [PubMed: 26070496]
7. Grossmann FF, Zumbrunn T, Frauchiger A, Delport K, Bingisser R, Nickel CH. At Risk of Undertriage? Testing the performance and accuracy of the emergency severity index in older emergency department patients. Ann Emerg Med. 2012; 60:317–325. [PubMed: 22401951]
8. Nakamura Y, Daya M, Bulger EM, Schreiber M, Mackersie R, Hsia RY, Mann NC, Holmes JF, Staudenmayer K, Sturges Z, Liao M, Haukoos J, Kuppermann N, Barton ED, Newgard CD. WESTRN Investigators. Evaluating age in the field triage of injured persons. Ann Emerg Med. 2012; 60(3):335–45. [PubMed: 22633339]
9. Calland JF, Ingraham AM, Martin N, Marshall GT, Schulman CI, Stapleton T, Barraco RD. Eastern Association for the Surgery of Trauma. Evaluation and management of geriatric trauma: An Eastern Association for The Surgery of Trauma Practice Management Guideline. J Trauma Acute Care Surg. 2012; 73(5 Suppl 4):S345–50. [PubMed: 23114492]
10. Centers for Disease Control and Prevention. Guidelines for field triage of injured patients: recommendations of the national expert panel on field triage. MMWR. 2012; 61(RR01):1–20.
11. Thompson HJ, Weir S, Rivara FP, Wang J, Sullivan SD, Salkever D, MacKenzie EJ. Utilization and costs of health care after geriatric traumatic brain injury. J Neurotrauma. 2012; 29:1864–1871. [PubMed: 22435729]
12. Farhad K, Khan HMR, Ji AB, Yacoub HA, Qureshi AI, Souayah N. Trends in outcomes and hospitalization costs for traumatic brain injury in adult patients in the United States. J Neurotrauma. 2013; 30:84–90. [PubMed: 22978433]
13. Peterson C, Xu L, Florence C, Grosse SD, Annest JL. Professional fee ratios for US hospital discharge data. Med Care. 2015; 53(10):840–849. [PubMed: 26340662]
14. Maryland Institute for Emergency Medical Services Systems. 2012–2013 Annual Report. Baltimore, MD 21201: Available at: https://www.miemss.org/home/Portals/0/Docs/AnnualReports/Annual_Report_2013B_Web2.pdf?ver=2013-10-16-105726-277 [Accessed 6/2/16]
15. Thurman, DJ., Sniezek, JE., Johnson, D., Greenspan, A., Smith, SM. Guidelines for surveillance of central nervous system injury. Centers for Disease Control and Prevention; Atlanta, GA: 1995.
16. Marr, A., Coronado, V., editors. Central nervous system injury surveillance data submission standards—2002. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; Atlanta, GA: 2004.
17. Carroll CP, Cochran JA, Guse CE, Wang MC. Are we underestimating the burden of traumatic brain injury? Surveillance of severe traumatic brain injury using Centers for Disease Control International Classification of Disease, Ninth revision, Clinical modification, traumatic brain injury codes. Neurosurgery. 2012; 71:1064–1070. [PubMed: 22922677]
18. Committee on Medical Aspects of Automotive Safety. Rating the severity of tissue damage I. The Abbreviated Scale. JAMA. 1971; 215:277–280. [PubMed: 5107365]

19. Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: A method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974; 14:187–196. [PubMed: 4814394]

20. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974; 13:81–4.

21. Schootman M, Buchman TG, Lewis LM. National estimates of hospitalization charges for the acute care of traumatic brain injuries. Brain Injury. 2003; 11:983–990.

22. Weir S, Salkever DS, Rivara FP, Jurkovich GJ, Nathens AB, Mackenzie EJ. One-year treatment costs of trauma care in the USA. Expert Rev Pharmacoecon Outcomes Res. 2010 Apr; 10(2):187–97. [PubMed: 20384565]

23. Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality; Rockville, MD: Nov. 2015 Cost-to-Charge Ratio Files. Available at: www.hcup-us.ahrq.gov/db/state/costtocharge.jsp [Accessed 5/9/16]

24. Centers for Medicare & Medicaid Services. [Accessed 6/13/16] FY 2012 Statewide Average Operating Cost-To-Charge Ratios for Acute Care Hospitals (Urban and Rural). Table 8A. Available at: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/FY-2012-IPPS-Final-Rule-Home-Page-Items/CMS1250520.html

25. The Maryland Health Services Cost Review Commission. [Accessed 7/26/16] Available at: http://www.hscrc.state.md.us/index.cfm

26. Rochette LM, Conner KA, Smith GA. The contribution of traumatic brain injury to the medical and economic outcomes of motor vehicle-related injuries in Ohio. J Safety Res. 2009; 40(5):353–358. [PubMed: 19932315]

27. 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; 30:2001–2013. [PubMed: 23962046]

28. Scheetz LJ. Injury patterns, severity and outcomes among older adults who sustained brain injury following a same level fall: a retrospective analysis. Int Emerg NUrs. 2015; 23(2):162–7. [PubMed: 25281285]

29. Curtis K, Chan DL, Lam MK, Mitchell R, King K, Leonard L, D'Amours S, Black D. The injury profile and acute treatment costs of major trauma in older people in New South Wales. Australas J Ageing. 2014 Dec; 33(4):264–70. [PubMed: 24520942]

30. McGarry LJ, Thompson D, Millham FH, Cowell L, Snyder PJ, Lenderking WR, Weinstein MC. Outcomes and costs of acute treatment of traumatic brain injury. J Trauma. 2002; 53:1152–1159. [PubMed: 12478043]

31. Morris S, Ridley S, Lecky FE, Munro V, Christensen MC. Determinants of hospital costs associated with traumatic brain injury in England and Wales. Anaesthesia. 2008; 63:499–508. [PubMed: 18412648]

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 1

Demographic and Clinical Characteristics of Admissions aged 65 and Older to the R Adams Cowley Shock Trauma Center 2008–2012 with Traumatic Brain Injury by Sex, n= 1,843

	Total, n=1,843	Women, n=882	Men, n=961	p-value[1]
Age (years), mean(SD)	78.3 (8.1)	79.9 (8.2)	76.8 (7.7)	<0.001
Age category, n(%)				<0.001
65–74	676 (37)	267 (30)	409 (43)	
75–84	700 (38)	331 (38)	369 (38)	
>84	467 (25)	284 (32)	183 (19)	
Race, n(%)				0.05
White	1,487 (81)	704 (80)	783 (81)	
Black	257 (14)	119 (13)	138 (14)	
Other	99 (5)	59 (7)	40 (4)	
Admission year, n(%)				0.75
2008	275 (15)	141 (16)	134 (14)	
2009	351 (19)	166 (19)	185 (19)	
2010	421 (23)	200 (23)	221 (23)	
2011	421 (23)	194 (22)	227 (24)	
2012	375 (20)	181 (21)	194 (20)	
Comorbid Conditions, n(%)				
Alcohol dependence	62 (3)	14 (2)	48 (5)	<0.001
Alzheimer's disease	69 (4)	43 (5)	26 (3)	0.01
Cardiac arrhythmia	102 (6)	44 (5)	58 (6)	0.33
COPD[2]	107 (6)	48 (5)	59 (6)	0.52
Diabetes	407 (22)	188 (21)	219 (23)	0.45
Depression	147 (8)	88 (10)	59 (6)	0.002
Heart failure	100 (5)	46 (5)	54 (6)	0.70
Ischemic heart disease	88 (5)	38 (4)	50 (5)	0.37
Neurologic disorders	112 (6)	47 (5)	65 (7)	0.20
Stroke	153 (8)	79 (9)	74 (8)	0.33
Admit SBP[3], mm Hg, mean (SD)	158.4 (36.5)	162.1 (35.1)	154.9 (37.4)	<0.001
Payer				<0.001
Medicare	1,504 (82)	753 (85)	751 (78)	
Auto Insurance	166 (9)	76 (9)	90 (9)	
Other	171 (9)	53 (6)	118 (12)	
ICU Stay, n(%)				<0.001
None	1,269 (69)	646 (73)	623 (65)	
< 2 days	125 (7)	50 (6)	75 (8)	
2 to <6 days	169 (9)	81 (9)	88 (9)	
6 to <12 days	144 (8)	62 (7)	82 (9)	
≥ 12 days	136 (7)	43 (5)	93 (10)	
Length of stay, n(%)				<0.001

	Total, n=1,843	Women, n=882	Men, n=961	p-value[1]
< 1 day	459 (25)	210 (24)	249 (26)	
1 to <2 days	251 (14)	132 (15)	119 (12)	
2 to <4 days	469 (25)	252 (29)	217 (23)	
4 to < 6 days	283 (15)	139 (16)	144 (15)	
6 to <14 days	208 (11)	92 (10)	116 (12)	
14 to <28 days	130 (7)	45 (5)	85 (9)	
≥ 28 days	43 (2)	12 (1)	31 (3)	
Expired at discharge, n(%)	294 (16)	120 (14)	174 (18)	0.008
Discharge location, n(%)				0.03
Home no services	607 (33)	283 (32)	324 (34)	
Home with services	49 (3)	27 (3)	22 (2)	
Inpatient	863 (47)	434 (49)	429 (45)	
Other	30 (2)	18 (2)	12 (1)	

[1]P-value from Chi-square goodness of fit or Student's t-test;

[2]Glasgow Coma Scale score;

[3]Amended Injury Severity Score (ISS) calculated by subtracting the square of the maximum Abbreviated Injury Scale score from the ISS.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 2

Injury Characteristics of Admissions aged 65 and Older to the R Adams Cowley Shock Trauma Center 2008–2012 with Traumatic Brain Injury by Sex, n=1,843

	Total, n=1,843	Women, n=882	Men, n=961	p-value[1]
Admission GCS[2], n(%)				0.002
14–15	1,349 (73)	649 (74)	700 (73)	
9–13	247 (13)	136 (15)	111 (12)	
3–8	247 (13)	97 (11)	150 (16)	
AIS, head, n(%)				0.02
1	377 (20)	173 (20)	204 (21)	
2	98 (5)	52 (6)	46 (5)	
3	312 (17)	166 (19)	146 (15)	
4	688 (37)	338 (38)	350 (36)	
≥5	368 (20)	153 (17)	215 (22)	
Amended ISS[3]				0.52
<9	1,356 (74)	655 (74)	701 (73)	
≥9	487 (26)	227 (26)	260 (27)	
Other injury location, n(%)				
None	536 (29)	251 (28)	285 (30)	0.57
Spine	351 (19)	158 (18)	193 (20)	0.24
Thorax	362 (20)	155 (18)	207 (22)	0.03
Abdomen	204 (11)	99 (11)	105 (11)	0.84
Lower extremities	422 (23)	211 (24)	211 (22)	0.32
Severity other injuries, n(%)				.60
No other injury	536 (29)	251 (28)	285 (30)	
Minor/moderate injury	778 (42)	383 (43)	395 (41)	
Serious injury	529 (29)	248 (28)	281 (29)	
Transport direct from scene, n(%)	990 (53)	464 (53)	526 (55)	0.36
Cause of injury, n(%)				<0.001
Motor vehicle collision	328 (18)	135 (15)	193 (20)	
Falls	1,417 (77)	729 (83)	688 (72)	
Assault	68 (4)	11 (1)	57 (6)	
Other injuries	30 (2)	7 (<1)	23 (2)	

[1] P-value from Chi-square goodness of fit, Student's t-test or Wilcoxon rank sum test;

[2] Glasgow Coma Scale score;

[3] Amended Injury Severity Score (ISS) calculated by subtracting the square of the maximum Abbreviated Injury Scale score from the ISS.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 3

Unadjusted Mean Hospital, Physician, and Total Charges of Admissions aged 65 and Older to the R Adams Cowley Shock Trauma Center 2008–2012 with Traumatic Brain Injury in 2012 Dollars

	Hospital charges Mean (SD)	STC[1] physician charges Mean (SD)	Total charges Mean (SD)	Total Charges Range
Total, n=1,843	30,651 (53,702)	5,425 (10,895)	36,075 (63,073)	1,761 – 848,262
Sex				
Male, n=961	36,877 (64,103)	6,796 (12,840)	43,673 (74,971)	2,344 – 848,262
Female, n=882	23,867 (38,260)	3,930 (8,015)	27,797 (45,404)	1,761 – 415,390
AIS[2] Head Score				
1, n=377	18,734 (34,604)	2,556 (5,813)	21,290 (39,667)	1,761 – 255,404
2, n=98	17,849 (32,552)	1,900 (3,461)	19,749 (35,277)	2,367 – 164,912
3, n=312	30,385 (59,807)	4,658 (9,970)	35,043 (68,797)	2,203 – 725,855
4, n=688	30,589 (48,003)	5,356 (11,270)	35,945 (58,025)	2,344 – 513,260
≥5, n=368	46,608 (71,960)	10,080 (14,211)	56,689 (83,606)	3,246 – 848,262
GCS[3]				
14–15, n=1,349	24,736 (44,054)	4,171 (9,575)	28,907 (52,317)	1,761 – 513,260
9–13, n=247	46,518 (81,890)	8,335 (13,735)	54,850 (93,170)	2,203 – 848,262
<9, n=247	47,088 (59,480)	9,364 (12,846)	56,452 (71,112)	2,606 – 470,471
Amended ISS[4]				
<9, n=1,356	22,557 (44,432)	4,220 (9,181)	26,777 (52,198)	1,761 – 848,262
≥9, n=487	53,187 (68,808)	8,780 (14,126)	61,966 (81,047)	2,362 – 725,855
Payer				
Medicare, n=1,504	28,338 (49,127)	5,070 (10,112)	33,408 (57,734)	1,761 – 848,262
Auto, n=166	42,983 (72,012)	7,031 (12,011)	50,014 (82,357)	1,953 – 725,855
Other, n=171	39,318 (67,808)	7,045 (15,344)	46,364 (81,749)	2,344 – 451,567
ICU[5] Stay, n(%)				
None, n=1,269	11,727 (13,930)	1,580 (750)	13,307 (15,433)	1,761 – 150,463
< 2 days. n=125	19,529 (33,420)	3,390 (6,165)	22,919 (38,623)	4,127 – 363,451
2 to <6 days, n=169	38,676 (26,445)	8,052 (8,478)	46,728 (31,899)	9,912 – 168,371
6 to <12 days, n=144	72,467 (69,315)	13,908 (9,594)	86,375 (75,292)	24,455 – 848,262
≥ 12 days, n=136	163,197 (86,120)	30,922 (26,479)	194,119 (101,813)	53,299 – 725,855
Length of Stay				
< 1 day, n=459	5,451 (6,251)	1,073 (2,561)	6,524 (7,260)	1,761- 101,143
1 to <2 days, n=251	7,559 (5,249)	1,455 (4,016)	9,014 (6,904)	3,276 – 58,556
2 to <4 days, n=469	12,675 (9,432)	1,783 (2,637)	14,459 (10,631)	3,948 – 117,117
4 to < 6 days, n=283	29,241 (21,715)	4,981 (6,861)	34,222 (26,265)	6,571 – 168,371
7 to <14 days, n=208	55,624 (30,033)	9,560 (8,634)	65,184 (35,702)	11,305 – 200,947

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

	Hospital charges Mean (SD)	STC[1] physician charges Mean (SD)	Total charges Mean (SD)	Total Charges Range
14 to <28 days, n=130	116,141 (48,277)	21,965 (12,894)	138,106 (57,160)	40,316 – 415,390
≥ 28 days, n=43	260,506 (128,766)	47,673 (23,605)	308,179 (141,511)	114,362 – 848,262
In Hospital Death				
No, n=1,549	27,963 (50,214)	4,769 (10,204)	32,732 (58,864)	1,761 – 848,262
Yes, n=294	44,809 (67,598)	8,879 (13,487)	53,688 (79,583)	2,606 – 725,855

[1] R Adams Cowley Shock Trauma Center;

[2] Abbreviated Injury Scale score;

[3] Glasgow Coma Scale;

[4] Injury Scale Score;

[5] Intensive Care Unit

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 4

Adjusted Mean Total Hospitalization Charges and Marginal Effects of Admissions aged 65 and Older to the R Adams Cowley Shock Trauma Center 2008–2012 with Traumatic Brain Injury, n=1,843

	Mean Charges in 2012 $ (95% Confidence Interval)	Marginal Effect (95% Confidence Interval)	p-value
Sex			
Male	36,167 (34,042, 38,292)	Reference	
Female	35,273 (33,146, 37,400)	-894 (-277, -1,512)	0.005
AIS Head Score			
1	35,170 (32,989, 37,350)	Reference	
2	35,307 (32,979, 37,635)	137 (-927, 1,202)	0.80
3	35,208 (32,986, 37,429)	38 (-914, 990)	0.94
4	35,813 (33,653, 37,973)	643(-185, 1,472)	0.13
≥5	36,763 (34,376, 39,149)	1,593 (103, 3,083)	0.04
Amended ISS			
<9	34,691 (32,559, 36,822)	Reference	
≥9	38,657 (36,272, 41,043)	3,967 (2,493, 5,440)	<0.001
ICU Stay, n(%)			
None	26,475 (23,864, 29,086)	Reference	
< 2 days	29,485 (26,340, 32,630)	3,010 (1,032, 4,989)	0.003
2 to <6 days	42,716 (37,717, 47,714)	16,241 (11,562, 20,920)	<0.001
6 to <12 days	56,979 (47,227, 66,732)	30,505 (20,191, 40,818)	<0.001
≥ 12 days	96,722 (71,698,121,746)	70,247 (43,779, 96,716)	<0.001
Length of Stay			
< 1 day	16,240 (13,841, 18,639)	Reference	
1 to <2 days	18,227 (15,785, 20,669)	1,986 (1,103, 2,870)	<0.001
2 to <4 days	22,629 (20,179, 25,079)	6,389 (5,380, 7,397)	<0.001
4 to < 6 days	34,603 (31,338, 37,868)	18,362 (15,665, 21,060)	<0.001
7 to <14 days	51,930 (45,795, 58,064)	35,689 (29,175, 42,204)	<0.001
14 to <28 days	90,101 (71,084, 109,119)	73,861 (53,415, 94,307)	<0.001
≥ 28 days	252,497 (186,121, 318,873)	236,657 (169,242, 303,272)	<0.001
In Hospital Death			
No	35,436 (33,315, 37,557)	Reference	
Yes	37,349 (34,819, 39,879)	1,913 (238, 3,588)	0.03