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Prevalence of Comorbidity and its Association with Traumatic Brain Injury and Outcomes in Older Adults

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Abstract

The study aims were to examine the association between age, comorbidity, and cause of injury in older adults with traumatic brain injury (TBI); and to determine which comorbidities relate to mortality, length of stay, and functional outcome at hospital discharge, controlling for initial injury severity, age, and sex. A retrospective cohort study design was used; clinical and outcome trauma registry data were obtained for 196 adults 55 and older with TBI. The majority had at least one comorbid condition (e.g., hypertension, alcohol abuse). In-hospital mortality was 31%. Among the oldest-old, motor vehicle collisions and falls were significantly associated with specific chronic diseases. Prior myocardial infarction was significantly associated with an increased risk of in-hospital death. Injury Severity Score and Glasgow Coma Scale score were predictive of discharge function, but comorbidity did not add significantly to the model. Primary TBI prevention efforts in older adults must consider the impact of comorbidity and cause of injury, particularly in the oldest-old. Alcohol abuse is common in older adults with TBI; screening should be conducted and interventions developed to prevent future injury. Future study is warranted to understand the interplay between pathophysiology of comorbid disease and injury and how to best manage rehabilitation within the context of aging.

In adults 65 and older, traumatic brain injury (TBI) is responsible for more than 80,000 emergency department (ED) visits each year in the United States; approximately three quarters of these adults require hospitalization as a result of their injury (Faul, Xu, Wald, & Coronado, 2010). In addition, adults 75 and older have the highest rates of TBI-related hospitalization in both the United States and Canada (Colantonio et al., 2010; Faul et al., 2010). Falls serve as the cause of injury for more than half of all TBIs incurred by older adults in the United States. While this information is important to guide general injury prevention activities, it offers little aid to nurses and other clinicians who aim to develop more effective methods targeted toward those most at risk, nor does it address the problem of TBI-related mortality and disability in older adults.

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Older age is a known variable to negatively influence outcome following TBI (Czosnyka et al., 2005; Hukkelhoven et al., 2003; Mosenthal et al., 2004). However, further data illuminating why this is the case, as well as information regarding age-appropriate care of older TBI patients, are either sparse or non-existent. Furthermore, despite the fact that the geriatric and neurotrauma literatures have identified the prognostic significance of the presence of chronic health conditions before injury (defined as comorbidity) on recovery after illness or injury, it remains understudied in the older adult TBI literature (Thompson, McCormick, & Kagan, 2006). The increasing prevalence of chronic health conditions coupled with the relative neglect of available studies on the presence of these conditions, their severity,' and treatment status leave many unanswered questions in the clinical management of older adults with TBI.

Thus, this study sought to address some of these gaps in the literature by addressing the following specific aims:

- To examine the association between age, comorbidity, and cause of injury in older adults with TBI.
- To determine which comorbid conditions relate to mortality, intensive care unit (ICU) and hospital length of stay (LOS), and functional outcome at hospital discharge, controlling for initial injury severity, age, and sex.

LITERATURE REVIEW

The issue of comorbidity in traumatic injury is becoming increasingly important with the "graying" of the population, as in the United States, approximately 80% of all adults 65 and older have at least one chronic condition and 50% have at least two (Centers for Disease Control and Prevention [CDC], 2003a). In 2007–2008 in the United States, 55.7% of community-dwelling adults 65 and older reported having hypertension, 31.9% reported a diagnosis of heart disease, 18.6% reported diabetes, and 8% reported having had a stroke (Federal Interagency Forum on Aging-Related Statistics, 2010). With the exception of stroke, these numbers represent increased prevalence from 2005–2007 (Federal Interagency Forum on Aging-Related Statistics, 2010). Mosenthal et al. (2004) reported that 73% of older TBI patients had a medical condition prior to injury, compared with only 28% of younger adults.

The presence of diabetes represents a clear example of the potential synergy between comorbid conditions and TBI. For example, the relative risk of falls in older adults with diabetes is 1.97 compared with those without diabetes (Kennedy et al, 2002). Of older adults who fall, up to 10% experience a significant injury such as TBI (Michael et al., 2010); thus by increasing risk of falls, diabetes may also increase risk of fall-related TBI. For this reason, targeting older adults with diabetes for TBI prevention activities may be appropriate and is an area for further study. Further, there is an association not only between diabetes and initial risk of injury but also between altered glucose regulation and injury-related mortality (Gale, Sicoutris, Reilly, Schwab, & Gracias, 2007; Laird, Miller, Kilgo, Meredith, & Chang, 2004; Sperry et al.,2007, 2009).

The presence of comorbid health conditions in older adults may also be associated with difficulty diagnosing new conditions or adverse responses to therapeutic interventions (Norris et al., 2008), which may result in complications. These complications may lead to increased length of stay, cost of care, and mortality (Grossman, Miller, Scaff, & Arcona, 2002; Taylor, Tracy, Meyer, Pasquale, & Napolitano, 2002).

To date, a single published study has examined the relationship between comorbidity and cause of injury. Coronado, Thomas, Sattin, and Johnson (2005) used the 15-state CDC TBI surveillance system database to examine the characteristics of hospitalized older adults with TBI. Fall-related TBI was associated with more recorded comorbid conditions than those injured in motor vehicle collisions (Coronado et al., 2005). Comorbid conditions that were similar between the two causes of injury included hypertension, diabetes mellitus, cardiac arrhythmias, and fluid and electrolyte disorders; however, those who fell had a higher prevalence of various neurological disorders. Limitations of this study included inability to control for severity of initial injury and prior health status—factors that may influence outcome. Further work is needed in this area to better clarify the influence of comorbid conditions on the occurrence of and outcomes following TBI in older adults, which is the purpose of this study.

METHOD

Design and Sample

The study protocol was approved by the University's Institutional Review Board. The retrospective cohort study design used multiple data sources: a data repository and retrospective medical record review.

Data Collection

Data Repository—The University's Traumatic Brain Injury Repository (TBIR) was used to identify patients for the current analysis. The TBIR contains aggregate data from more than 2,700 adult patients admitted with a diagnosis of TBI for the past 10 years, gathered from multiple clinical studies. Patient demographic data and outcome data (length of hospital stay, mortality [alive or deceased] during index hospitalization *[yes/no]*) are available within the data set.

Eligibility Criteria—Patients 55 and older in the TBIR database who experienced blunt (non-penetrating) head injury were eligible for the current study ($N = 196$).

Retrospective Medical Record Review—Medical records from the patient's index hospitalization were obtained and reviewed by a trained staff member or the principal investigator (H.J.T.) to identify comorbid conditions present pre-injury.

Demographic Data—Data extracted from the repository included age at time of injury, date of injury, sex, and race/ethnicity.

Comorbid Health Conditions—Thirty-four chronic conditions, as listed in the Elixhauser measure (Elixhauser, Steiner, Harris, & Coffey, 1998), plus the additional category of vision disturbance were used to categorize comorbid conditions as present or absent pre-injury. In the Elixhauser list, severity of two conditions—diabetes and liver disease—are further classified as "severe," based on other system effects. Conditions were identified and extracted from the patient's medical record after review by a trained staff member or the principal investigator. The total count of concurrent symptomatic pre-existing conditions was also calculated (Grimby & Svanborg, 1997), with higher numbers indicating greater number of pre-existing conditions.

Injury-Related Data—Injury data were obtained from the TBIR and verified with hospital trauma registry data to provide a quality check of the extracted data. Data included information on injury severity (Glasgow Coma Scale, GCS, and Injury Severity Score, ISS). The GCS is a measure of depth of impaired consciousness following TBI or other disorders (Teasdale & Jennett, 1974). For the purposes of this study, we used the first reported GCS in the ED. The GCS is scored from 3 to 15, with higher scores indicating greater neurological function. The ISS (Baker, O'Neill, Haddon, & Long, 1974) is a measure of the overall severity of multiple trauma. Originally developed to predict mortality in trauma patients, the ISS has also been used to adjust for case-mix in epidemiological studies of trauma. The ISS is the sum of the squares of the most severe injury in each of the three most severely injured body regions and is scored on a scale of 1 *(least severe)* to 75 *(most severe)* (Baker & O'Neill, 1976). The inter-rater agreement for injury severity rating of blunt injury has been reported to be between 74% and 87% (MacKenzie, 1984). The six body regions on which the ISS is based are head/neck, face, chest, abdomen/pelvic contents, extremities/pelvic girdle, and external. The ISS has been shown to be highly sensitive and specific for prediction of outcome across different trauma populations, including older adults (Bull, 1975). The predictive ability (receiver operating characteristic, ROC) for mortality of the ISS has been reported to be 0.86 to 0.88 in different populations (Bolorunduro et al., 2011; Meredith et al., 2002).

Outcomes—The outcome of interest for the first study aim was cause of injury, which was taken from the TBIR. In the TBIR, cause of injury was extracted from E-group coding in the medical record. E-group codes are supplemental data to the *International Classification of Diseases,* ninth revision, clinical modification, reported in hospital discharge data that specify the cause (mechanism), as well as the intent (e.g., unintentional, violence-related, self-inflicted) of injury (CDC, 2005). For the purposes of this study, we used only the cause of injury. Previous studies have reported this to be a reliable and valid method of extracting information on cause of injury, with overall agreement between coders to be greater than 87% (Bergstrom, Byberg, Melhus, Michaelsson, & Gedeborg, 2011; LeMier, Cummings, & West, 2001; McKenzie et al., 2009).

The outcomes of interest for the second study aim were ICU LOS, hospital LOS, in-hospital mortality, and modified Functional Independence Measure (mFIM, Mosenthal et al., 2004) at discharge. The mFIM consists of three items; locomotion, feeding, and communication, each rated on a scale of 1 *(total dependence)* to 4 *(total independence)*. Total scores range from 3 to 12, with lower scores indicating greater dependence (Mosenthal et al., 2004).

Data Analyses

Descriptive statistics were performed to describe the sample and the prevalence of comorbid health conditions. We classified patients into age categories: young-old (55 to 74), middle-old (75 to 84) and oldest-old (85+). Chisquare tests were used to determine whether comorbidity and age group were predictive of cause of injury. The relationship between the prevalent comorbid health conditions and discharge mortality was assessed using binary logistic regression. Linear regression analyses were conducted to assess for the influence of comorbidity on LOS and mFIM score. Covariates controlled for in the analyses included age, sex, and severity of initial, injury (GCS and ISS). Area under the curve (c-statistic) was calculated to determine the predictive ability of the Elixhauser score for mortality in this sample using ROC analysis. All p values were two tailed, and a value of <0.05 was considered statistically significant; no adjustment was made for multiple comparisons. All analyses were performed using SPSS version 15.0.

RESULTS

Sample characteristics are presented in Table 1. Patients' GCS scores ranged across the full scale (3 to 15), with a mean of 9.9. Sixty percent of the sample was within the range of 3 to 12 and were classified as severe or moderate TBI, Average ISS score was 25.6, well above the threshold of 15, which indicates major trauma.

Although the investigators reviewed the entire medical record for the index hospitalization, data on pre-existing comorbid health conditions were absent from the medical record in 34 cases (17.3% of charts). Complete data for comorbidity analysis were available on only 162 of the 196. Hypertension was the most commonly found pre-existing condition (41.4%), followed by alcohol abuse (25.3%) (Table 2).

After controlling for age, sex, and injury severity, the only comorbid disease that was significantly associated with an increased risk of in-hospital death (p = O.001) in patients with TBI was prior myocardial infarction (MI): relative risk (RR) = 14.3, 95% confidence interval (CI) = 2.1, 97.1. There was also a trend toward an increased risk of in-hospital death in those with coronary artery disease (RR = 4.2, 95% CI = 0.97, 18.0), but we cannot reject the null hypothesis. The Elixhauser score had low sensitivity and specificity for prediction of mortality, with an area under the curve of only 0.47 (CI = 0.37, 0.47), meaning it did no better than chance alone.

Interestingly, comorbidity was significantly related to ICU LOS (Table 3) but not hospital LOS (data not shown), explaining an additional 4% of the total variance in ICU LOS. Of injury-related and demographic variables, only ISS and GCS scores were independently significantly predictive of discharge function (Table 4). When comorbidity, as measured by Elixhauser score, was added, it explained less than 1% of the total variance in function at discharge. We also explored the association between the presence of pre-injury conditions and level of discharge function but found no association (data not shown).

In exploratory examinations of the interactions among age, presence of chronic disease, and cause of injury, several differences were found. Falls were more common among those with a history of alcohol abuse (χ^2 = 6.38, p = 0.04) in the young-old. Among the oldest-old, motor vehicle collisions were significantly more likely to be the cause of injury in those with either a diagnosis of congestive heart failure (χ^2 = 13.4, p = 0.001) or endocrine disorders (χ^2 = 14.*7*, p = 0.001), whereas falls were more likely in those with a comorbid vision problem such as cataracts (χ^2 = 7.5, P = 0.02).

DISCUSSION

The purpose of this study was to determine the relationship between pre-injury comorbidity and TBI, both in terms of the cause of the initial injury (i.e., reason) and outcome (i.e., function and mortality). Although history is often unobtainable on trauma patients at admission to the ED, we found that more than 15% of older adults had no documentation about medical history during the entire index hospitalization. This was despite an average LOS of more than 21 days. In the current study, those who died early were no more likely than those who died later or who survived to have missing comorbidity data. Improved efforts by health care providers to obtain and document medical history are necessary to ensure chronic health conditions and usual medications are noted, as the absence of this information may delay or complicate diagnosis and treatment in older trauma patients (Norris et al., 2008).

Analysis of our data corroborates and extends prior work in which hypertension was found to be the most prevalent condition and diabetes, cardiac arrhythmias, and chronic pulmonary disease were also common conditions seen in older adults with TBI (Coronado et al., 2005). In contrast to this prior study, however, we found that alcohol abuse was the second most prevalent condition in older adults with TBI. Screening for alcohol abuse, using an instrument validated in TBI patients, such as the CAGE instrument (Ashman, Schwartz, Cantor, Hibbard, & Gordon, 2004), should be done on all patients with TBI. And because pre-injury alcohol abuse is associated with problem drinking in the year post-injury

(Bombardier, Temkin, Machamer, & Dikmen, 2003), there is also a need to identify targeted interventions that reduce alcohol consumption and abuse in older adults following traumatic injury (Andelic et al., 2010). In the current study, falls were more commonly experienced as the cause of injury among the young-old TBI patients with comorbid alcohol abuse. Euture studies should focus on fall type (e.g., ground level versus fall from height) and circumstances surrounding the fall in order to develop targeted interventions to be tested as a part of further risk-reduction strategies.

In this study, falls were more likely in the oldest-old with a comorbid vision problem. In contrast to current CDC recommendations (Stevens & Sogolow, 2008), a recent systematic review of fall prevention strategies found no evidence that vision correction reduced the proportion of falls and some limited evidence that it may actually increase falls in some older adults due to increase in physical activity (Michael et al., 2010). Therefore, further research to create evidence-based recommendations for vision screening and correction in older adults are needed.

In-hospital mortality in this study was relatively high (31%) compared with prior studies. In a 1999 national sample of Medicare patients, in-hospital mortality following TBI was reported to be only 14.3% (Donohue, Clark, & DeLorenzo, 2007), whereas others have reported mortality rates similar to that in this study (30%) (Mosenthal et al., 2002). To be able to draw comparisons across studies of TBI, it is essential to understand differences in sample distribution or to know whether adjustment for initial injury severity was made, as the variation seen in mortality rates could be related to injury severity in the various study samples. The majority of TBIs in the United States (approximately 75%) are mild (CDC, 2003b). Our sample was skewed toward a higher severity of injury, with only 40% of those in the sample having mild injury (GCS score of 13 to 15) on admission to the ED, likely related to inclusion criteria for clinical trials, which formed the basis for the TBIR. The average initial GCS in the current study was similar to that reported by Mosenthal et al. (2002) (moderate severity 9.9 versus 10.5); thus, it is not surprising that we report a similar overall mortality rate. In the current study we found prior MI to be associated with a significantly increased risk of mortality, but the very wide confidence intervals indicate that the estimates may be somewhat unreliable. Neither the time since MI nor the severity/ current impact on cardiac function is accounted for by this simple assessment, which may be causing the wide variability in estimating the effect of MI on mortality.

While the Elixhauser score accounted for 4% of the variance in ICU LOS, we are unable to discern the underlying reason (e.g., related to delay in diagnosis, increased number of complications), Further, the Elixhauser score (total number of comorbid conditions) had low sensitivity and specificity for prediction of discharge mortality and explaining discharge function in the current study. This is similar to prior findings with the Charlson Comorbidity Index and prediction of hospital mortality following all-cause trauma (Gabbe, Magtengaard, Hannaford, & Cameron, 2005; Thompson et al., 2010). In the study by Thompson et al, comorbidity was found to play a larger role in mortality in the year following discharge. Future study is warranted to understand the interplay between comorbid disease pathophysiology and the complexity of injury recovery, as well as how to best manage rehabilitation within the context of aging and chronic disease to achieve optimal functional outcomes and quality of life for older adults. Studies to date have primarity conceptualized comorbidity as the presence of additional conditions or a simple count of the number of chronic health conditions. We note the need to move away from this conceptualization to a more granular approach that incorporates length of diagnosis, treatment status, and effect on functional status in order to more fully understand the implications of comorbidity on outcomes.

LIMITATIONS

This study had several limitations that reduce its generalizability. First, the patients were obtained from an existing TBI data registry, which may be subject to enrollment bias as the registry was formed from a collation of ongoing and completed TBI clinical trials and therefore is not population based. Second, due to established age-related exclusion criteria in clinical trials, few adults classified as oldest-old (85+) were available for inclusion in sample. Future work needs to include more representative sampling of this group as they are at high risk of injury and death. A substantive limitation of the current study is that the number of chronic health conditions studied creates the issue of multiple comparisons in the analyses, increasing the likelihood of a Type I error. Thus, the study findings should be interpreted as initial and exploratory; follow-up confirmatory studies are needed with larger samples. Another limitation of the sample was that it was predominantly White, which while it reflects the local community and trial participants, is not reflective of the overall U.S. or older adult TBI demographics. Future studies need to be cognizant of the disparities in available TBI research that include historically disadvantaged groups and seek population-based representation, particularly within clinical trials.

As a secondary data analysis, some data known to influence recovery following injury, such as pre-injury functional status, financial status, and social support, were not available for analysis in the registry or medical records. While insurance status has been used as a proxy of financial status in prior studies (Thompson et al., 2008) and has been shown to be related to outcome in some studies of TBI in older adults (Alban et al., 2010), this is not as useful. We did not examine the effects of length of disease or treatment status of health conditions on outcome, which are possible confounding variables and are areas for future inquiry.

CONCLUSION

With the growing population of older adults in the United States and globally, there is an urgent need for strategies that reduce the risk of injury to address the growing public health concern of TBI. With the prevalence of chronic disease increasing, it is important to recognize those conditions that may put older adults at increased risk of TBI in order to intervene early, specifically, and effectively. Nurse researchers are in a unique position to provide guidance to and lead these health promotion efforts. Particular attention needs to be given to the development of evidence-based interventions for reduction of alcohol consumption and abuse in all injured older adults. In addition, to promote optimal outcomes, future work needs to focus on understanding the pathobiology that occurs when aging, comorbid disease, and injury intersect.

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REFERENCES

Alban RF, Berry C, Ley E, Mirocha J, Margulies DR, Tillou A, Salim A. Does health care insurance affect outcomes after traumatic brain injury? Analysis of the National Trauma Databank. The American Surgeon. 2010; 76:1108–1111. [PubMed: 21105621]

Andelic N, Jerstad T, Sigurdardottir S, Schanke AK, Sandvik L, Roe C. Effects of acute substance use and pre-injury substance abuse on traumatic brain injury severity in adults admitted to a trauma centre. Journal of Trauma Management & Outcomes. 2010; 4 Retrieved from http://www.trauma-management.org/content/4/1/6.

Ashman TA, Schwartz ME, Cantor JB, Hibbard MR, Gordon WA. Screening for substance abuse in individuals with traumatic brain injury. Brain Injury. 2004; 18:191–202. [PubMed: 14660230]

Baker SP, O'Neill B. The injury severity score: An update. Journal of Trauma. 1976; 16:882–885. [PubMed: 994270]

Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. Journal of Trauma. 1974; 14:187–196. [PubMed: 4814394]

Bergstrom MF, Byberg L, Melhus H, Michaelsson K, Gedeborg R. Extent and consequences of misclassified injury diagnoses in a national hospital discharge registry. Injury Prevention. 2011; 17:108–113. [PubMed: 21113015]

Bolorunduro OB, Villegas C, Oyetunji TA, Haut ER, Stevens KA, Chang D, Haider AH. Validating the Injury Severity Score (ISS) in different populations: ISS predicts mortality better among Hispanics and females. Journal of Surgical Research. 2011; 166:40–44. [PubMed: 20828742]

Bombardier CH, Temkin NR, Machamer J, Dikmen SS. The natural history of drinking and alcohol-related problems after traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2003; 34:185–191. [PubMed: 12601648]

Bull JP. The injury severity score of road traffic casualties in relation to mortality, time of death, hospital treatment time and disability. Accident Analysis & Prevention. 1975; 7:249–255.

Centers for Disease Control and Prevention. Public health and aging: Trends in aging—United States and worldwide. Morbidity and Mortality Weekly Report. 2003a; 52 Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5206a2.htm.

Centers for Disease Control and Prevention. Report to Congress on mild traumatic brain injury in the United States: Steps to prevent a serious public health problem. 2003b. Retrieved from http://www.cdc.gov/ncipc/pub-res/mtbi/mtbireport.pdf

Centers for Disease Control and Prevention. Matrix of E-code groupings: Table 1. Recommended framework of E-code groupings for presenting injury mortality and morbidity data. In Injury prevention & control: Data & statistics (WISQARS™). 2005. Retrieved from http://www.cdc.gov/ncipc/whatsnew/matrix2.htm

Colantonio A, Saverino C, Zagorski B, Swaine B, Lewko J, Jaglal S, Vernich L. Hospitalizations and emergency department visits for TBI in Ontario. Canadian Journal of Neurological Science. 2010; 37:783–790.

Coronado VG, Thomas KE, Sattin RW, Johnson RL. The CDC traumatic brain injury surveillance system: Characteristics of persons aged 65 years and older hospitalized with a TBI. Journal of Head Trauma Rehabilitation. 2005; 20:215–228. [PubMed: 15908822]

Czosnyka M, Balestreri M, Steiner L, Smielewski P, Hutchinson PJ, Matta B, Pickard JD. Age, intracranial pressure, autoregulation, and outcome after brain trauma. Journal of Neurosurgery. 2005; 102:450–454. [PubMed: 15796378]

Donohue JT, Clark DE, DeLorenzo MA. Long-term survival of Medicare patients with head injury. Journal of Trauma. 2007; 62:419–423. [PubMed: 17297334]

Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Medical Care. 1998; 36:8–27. [PubMed: 9431328]

Faul, M.; Xu, L.; Wald, MM.; Coronado, VG. Traumatic brain injury in the United States: Emergency department visits, hospitalizations and deaths 2002–2006. 2010. Retrieved from http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf

Federal Interagency Forum on Aging-Related Statistics. Older Americans 2010: Key indicators of well-being. 2010. Retrieved from http://www.agingstats.gov/Main_Site/Data/2010_Documents/docs/Introduction.pdf

Gabbe BJ, Magtengaard K, Hannaford AP, Cameron PA. Is the Charlson Comorbidity Index useful for predicting trauma outcomes? Academic Emergency Medicine. 2005; 12:318–321. [PubMed: 15805322]

Gale SC, Sicoutris C, Reilly PM, Schwab CW, Gracias VH. Poor glycemic control is associated with increased mortality in critically ill trauma patients. The American Surgeon. 2007; 73:454–460. [PubMed: 17520998]

Grimby A, Svanborg A. Morbidity and health-related quality of life among ambulant elderly citizens. Aging. 1997; 9:356–364. [PubMed: 9458996]

Grossman MD, Miller D, Scaff DW, Arcona S. When is an elder old? Effect of preexisting conditions on mortality in geriatric trauma. Journal of Trauma. 2002; 52:242–246. [PubMed: 11834982]

Hukkelhoven CW, Steyerberg EW, Rampen AJ, Farace E, Habbema JD, Marshall LF, Maas AL. Patient age and outcome following severe traumatic brain injury: An analysis of 5600 patients. Journal of Neurosurgery. 2003; 99:666–673. [PubMed: 14567601]

Kennedy RL, Henry J, Chapman AJ, Nayar R, Grant P, Morris AD. Accidents in patients with insulin-treated diabetes: Increased risk of low-impact falls but not motor vehicle crashes—A prospective register-based study. Journal of Trauma. 2002; 52:660–666. [PubMed: 11956379]

Laird AM, Miller PR, Kilgo PD, Meredith JW, Chang MC. Relationship of early hyperglycemia to mortality in trauma patients. Journal of Trauma. 2004; 56:1058–1062. [PubMed: 15179246]

LeMier M, Cummings P, West TA. Accuracy of external cause of injury codes reported in Washington State hospital discharge records. Injury Prevention. 2001; 7:334–338. [PubMed: 11770664]

MacKenzie EJ. Injury severity scales: Overview and directions for future research. American Journal of Emergency Medicine. 1984; 2:537–549. [PubMed: 6442155]

McKenzie K, Enraght-Moony EL, Waller G, Walker SM, Harrison JE, McClure RJ. Causes of injuries resulting in hospitalisation in Australia: Assessing coder agreement on external causes. Injury Prevention. 2009; 15:188–196. [PubMed: 19494099]

Meredith JW, Evans G, Kilgo PD, MacKenzie E, Osler T, McGwin G, Champion HR. A comparison of the abilities of nine scoring algorithms in predicting mortality. Journal of Trauma. 2002; 53:621–628. [PubMed: 12394857]

Michael, YL.; Whitlock, EP.; Lin, JS.; Fu, R.; O'Connor, EA.; Gold, R. Primary care-relevant interventions to prevent falling in older adults: A systematic evidence review for the U.S. Preventive Services Task Force. 2010. Retrieved from the U.S. Preventive Services Task Force website: http://www.uspreventiveservicestaskforce.org/uspstf11/fallsprevention/fallsprevart.htm

Mosenthal AC, Lavery RF, Addis M, Kaul S, Ross S, Marburger R, Livingston DH. Isolated traumatic brain injury: Age is an independent predictor of mortality and early outcome. Journal of Trauma. 2002; 52:907–911. [PubMed: 11988658]

Mosenthal AC, Livingston DH, Lavery RF, Knudson MM, Lee S, Morabito D, Coimbra R. The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multicenter trial. Journal of Trauma. 2004; 56:1042–1048. [PubMed: 15179244]

Norris SL, High K, Gill TM, Hennessy S, Kutner JS, Reuben DB, Landefeld CS. Health care for older Americans with multiple chronic conditions: A research agenda. Journal of the American Geriatrics Society. 2008; 56:149–159. [PubMed: 18047493]

Sperry JL, Frankel HL, Nathens AB, O'Keefe GE, Cuschieri J, Moore EE, Minei JP. Characterization of persistent hyperglycemia: What does it mean postinjury? Journal of Trauma. 2009; 66:1076–1082. [PubMed: 19359917]

Sperry JL, Frankel HL, Vanek SL, Nathens AB, Moore EE, Maier RV, Minei JP. Early hyperglycemia predicts multiple organ failure and mortality but not infection. Journal of Trauma. 2007; 63:487–493. [PubMed: 18073591]

Stevens, JA.; Sogolow, ED. Preventing falls: What works. A CDC compendium of effective community-based interventions from around the world. 2008. Retrieved from the Centers for Disease Control and Prevention website: http://www.cdc.gov/HomeandRecreationalSafety/images/CDCCompendium_030508-a.pdf

Taylor MD, Tracy JK, Meyer JK, Pasquale M, Napolitano LM. Trauma in the elderly: Intensive care unit resource use and outcome. Journal of Trauma. 2002; 53:407–414. [PubMed: 12352472]

Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974; 2:81–84. [PubMed: 4136544]

Thompson HJ, McCormick WC, Kagan SH. Traumatic brain injury in older adults: Epidemiology, outcomes, and future implications. Journal of the American Geriatrics Society. 2006; 54:1590–1595. [PubMed: 17038079]

Thompson HJ, Rivara FP, Jurkovich GJ, Wang J, Nathens A, MacKenzie EJ. An evaluation of the effect of intensity of care on mortality following traumatic brain injury. Critical Care Medicine. 2008; 36:282–290. [PubMed: 18007264]

Thompson HJ, Rivara FP, Nathens A, Wang J, Jurkovich GJ, Mackenzie EJ. Development and validation of the mortality risk for Trauma Comorbidity Index. Annals of Surgery. 2010; 252:370–375. [PubMed: 20622665]

TABLE 1

Demographic and Injury Data for the Sample (*N* = 196)

Variable	Mean (*SD*)
Age (years)	69.3 (10)
Injury severity	
Glasgow Coma Scale score	9.9 (4)
Injury Severity Score	25.6 (9)
Elixhauser score[a]	1.7 (1)
Modified Functional Independence Measure score	8.7 (3)
Length of hospital stay (days)	21.6 (24)
	n (%)
Sex	
Men	139 (70.9)
Women	57 (29.1)
Race	
White	173 (88.3)
Asian	7 (3.6)
Black	5 (2.6)
Native American	4 (2)
Other	7 (3.5)
Cause of injury	
Fall	81 (41.3)
Pedestrian hit by vehicle	39 (19.9)
Motor vehicle collision	34 (17.3)
Other vehicle collision (e.g., bicycle)	7 (3.6)
Struck by object	7 (3.6)
Assault	4 (2)
Other, not specified	24 (12.2)
In-hospital mortality	61 (31.1)

[a] *n* = 162.

Note. The Glasgow Coma Scale is a measure of depth of impaired consciousness following traumatic brain injury or other disorders (Teasdale & Jennett, 1974), scored from 3 to 15, with higher scores indicating greater neurological function; The Injury Severity Score is the sum of the squares of the most severe injury in each of the three most severely injured body regions, scored from 1 (*least severe*) to 75 (*most severe*) (Baker & O'Neill, 1976); The Elixhauser score is a count of concurrent pre-existing medical conditions, with higher numbers indicating more conditions present (Elixhauser, Steiner, Harris, & Coffey, 1998); The modified Functional Independence Measure consists of three items: locomotion, feeding, and communication, each rated on a scale of 1 (*total dependence*) to 4 (*total independence*), with total scores ranging from 3 to 12 and lower scores indicating greater dependence (Mosenthal et al., 2004).

TABLE 2

Ten Most Prevalent Comorbid Conditions in Older Adults with TBI (*n* = 162)

Condition	*n* (%)
Hypertension	67 (41.4)
Alcohol abuse	41 (25.3)
Cardiac arrhythmias	18 (11.1)
Coronary artery disease	16 (9.9)
Diabetes	15 (9.3)
Chronic pulmonary disease	14 (8.6)
Myocardial infarction	12 (7.4)
Rheumatoid arthritis	12 (7.4)
Other neurological problem	10 (6.2)
Anemia	9 (5.6)

Note. TBI = traumatic brain injury. Data were extracted from patients' medical records.

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TABLE 3

Effect of Comorbidity on Intensive Care Unit Length of Stay Following TBI

Variable	R^2	Change in R^2	β	*t* Value	*p* Value
Step 1					
Age			−0.020	−0.237	0.813
Sex			−0.082	−0.949	0.345
ISS			0.522	5.48	<0.0005
GCS score	0.251	0.251	0.113	1.20	0.234
Step 2					
Age			−0.035	−0.417	0.678
Sex			−0.057	−0.667	0.506
ISS			0.593	−6.08	<0.0005
GCS score			0.121	1.30	0.196
Comorbidity (Elixhauser score)	0.291	0.040	0.212	2.45	0.016

Note. TBI = traumatic brain injury; ISS = Injury Severity Score; GCS = Glasgow Coma Scale.

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TABLE 4

Effect of Comorbidity on Functional Outcome at Hospital Discharge Following TBI

Variable	R^2	Change in R^2	β	*t* Value	*p* Value
Step 1					
Age			−0.015	−0.133	0.895
Sex			0.093	0.802	0.426
ISS			−0.336	−2.80	0.007
GCS score	0.358	0.358	0.361	3.11	0.003
Step 2					
Age			−0.011	−0.094	0.926
Sex			0.088	0.757	0.452
ISS			−0.349	−2.81	0.007
GCS score			0.353	2.99	0.004
Comorbidity (Elixhauser score)	0.360	0.003	−0.052	−0.467	0.643

Note. TBI = traumatic brain injury; ISS = Injury Severity Score; GCS = Glasgow Coma Scale.