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Association between pediatric TBI mortality and median family income in the United States: A retrospective cohort study

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Summary

Background—There are regional disparities in pediatric traumatic brain injury (TBI) mortality across the United States, but the factors underlying these differences are unclear.

Methods—We performed a retrospective cross-sectional analysis of the Pediatric Health Information System database including inpatient hospital encounters for children less than 18 years old with a primary diagnosis of TBI between 2010–2019.

Findings—Lower median family income was associated with pediatric TBI mortality. Encounters from zip-codes with a median family income of <$20,000 had a 3.1% (29/950) mortality, as opposed to 1.3% (29/2,267) mortality for zip-codes with a median family income

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Contributors
Dr. Pelletier conceptualized the study, performed database extraction, performed statistical coding, and wrote the first draft of the manuscript. Dr. Rakkar performed statistical coding and substantially revised the work. Drs. Simon, Au, Fuhrman, Clark, Kochanek, and Horvat, reviewed the initial draft of the manuscript, contributed additional analyses, and substantially revised the work. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Data Sharing Statement
The data used to generate this manuscript is contained in the Pediatric Health Information Systems, owned by the Children's Hospital Association. While the authors cannot distribute the data, interested hospitals may join the Children's Hospital Association via their website www.childrenshospitals.org.

Declaration of interests
The authors have no conflicts of interest relevant to this article to disclose.

Supplementary materials
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of >$80,000 ($p = 0.00096$). In multivariable logistic regression, every $10,000 of income was associated with an odds ratio of mortality of 0.94 (95% confidence interval 0.90 – 0.98). 82.5% (397/481) of ballistic TBI injuries were caused by a firearm. Lower income was associated with a higher proportion of ballistic TBI injuries (2.5% [24/950] for <$20,000 versus 0.3% [7/2,267] for >$80,000, $p < 0.0001$). In multivariable logistic regression, ballistic TBI injuries were associated with an odds ratio of mortality of 5.19 (95% confidence interval 4.00 – 6.73). United States regional variation in pediatric TBI mortality was linearly associated with the percentage of ballistic TBI (adjusted r-squared 0.59, $p = 0.0097$).

Interpretation—Children from lower income zip-codes are more likely to sustain a ballistic TBI, and more likely to die. Further work is necessary to determine causal factors underlying these associations and to design interventions that prevent these injuries and/or improve outcomes.

Keywords

Traumatic brain injury; mortality; pediatrics; epidemiology

Introduction

Pediatric traumatic brain injury (TBI) has a worldwide incidence of 47–280 per 100,000 children, with male predominance after age three years.[1] The estimated annual incidence of pediatric TBI in the United States (US) is ~70/100,000 children, with a bimodal age distribution, peaking at ages less than five years old and in the late teenage years.[1,2] While US pediatric TBI mortality decreased between 2000–2010, associated with decreased automobile-related TBI, mortality rates between 2010–2017 increased slightly, predominantly driven by increases in suicides and firearm violence.[3]

US pediatric and adult TBI mortality varies by region, with higher mortality in more rural areas and the southeastern US.[3–5] However, it is unclear whether these outcomes are related to differences in TBI mechanisms,[3,6] access to pediatric trauma centres,[7,8] or other factors. The relationship between socioeconomic factors and pediatric TBI mortality is also unclear. Single-center and county-level studies have come to varying conclusions regarding the influence of socioeconomic status on pediatric trauma outcomes.[9,10] Lastly, the effects of the rise in the incidence of TBI caused by firearm violence[3] on pediatric TBI mortality are also not well described.

Given this uncertainty, we sought to analyze sociodemographic and regional factors associated with pediatric TBI mortality using a large multi-centre database of US children's hospitals.[11]

Methods

Study Design and Setting

This was a retrospective cross-sectional study of inpatient admissions in PHIS, an online, quality controlled, anonymized, administrative data warehouse of 51 children's hospitals across the US maintained by the Children's Hospital Association (CHA).[11,12] Demographic variables extracted included race (self-reported and categorized into White, Black or African

American, American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, and other, as required by the United States Office of Management and Budget)[13], ethnicity (Hispanic or Not Hispanic), age, sex, Rural-Urban Commuter Area (RUCA) codes,[14] zip-code median income, admission diagnosis, intensive care unit (ICU) admission, use of invasive mechanical ventilation (IMV), and complex chronic conditions (CCC).[15,16]

To ensure that changes in admission numbers reflected seasonal trends, rather than database expansion (as the PHIS database has grown over the past decade)[11] we restricted the analysis to hospitals providing data since 2010. Patients age zero to eighteen years were eligible for inclusion if they were discharged between January 1st, 2010 and December 31st, 2019 from one of the PHIS centres with a primary encounter diagnosis of TBI, according to International Classification of Diseases (ICD) version 9 or version 10 codes, as defined by the US Military Health System.[17] Diagnoses were filtered to exclude sequela and subsequent encounters. Hospitals were grouped according to their US Census Division.[18] Outcomes included the number of monthly and annual admissions over time, and in-hospital mortality, defined in PHIS.[11] This study was granted an exemption by the University of Pittsburgh Institutional Review Board, as it was a secondary analysis of an anonymized database. This manuscript follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines for cross-sectional studies.[19]

Statistical Analyses

Cohort demographics were described using summary statistics and t-tests, chi-square tests, or Fisher exact tests as appropriate. Hospital charges were adjusted by the Centers for Medicare & Medicaid Services (CMS) wage/price index according to hospital zip code in PHIS.[11] Charge-over-time analyses were adjusted for the quarterly Gross Domestic Product (GDP) provided by the Bureau of Economic Analysis and expressed in 2010 dollars.[20] Patients were classified as having ballistic TBI if their encounter included a secondary diagnostic code for ballistic injuries. For analyses incorporating family income, each encounter was mapped to patient-level zip-code 2010 median family income using PHIS. Admission numbers were transformed into time-series data based on the date of admission and mapped to US Census Region. Chi-square testing was used to compare mortality proportions across hospitals, regions, and time. Seasonality testing was performed using Webel and Ollech’s method.[21] Admission season was defined as winter (December-February), spring (March-May), summer (June-August), or autumn (September-November) per United States weather patterns. Quantification of seasonal trends in admission rates between 2010–2019 were displayed using LOcally Estimated Scatterplot Smoothing (LOESS).[22] For analyses considering RUCA codes,[14] zip-code level RUCA codes were extracted from PHIS and categorized according to population density and geographic isolation to match the categorizations of the US Census Bureau.[23,24]

To understand whether income and ballistic injuries were associated with TBI mortality after adjustment for confounders, we trained a stepwise multivariable logistic regression model using data available at the time of admission, including demographics, geography, seasonality, and admission diagnosis based on imaging findings using k-fold cross-validation.[25] Age was included as a spline with knots at 1, 5, 10, and 15 years, as these groups were previously known to display differing mortality trends.[3] The linearity assumption for income and mortality was verified by visual inspection before model development.

To understand whether regional disparities in income and ballistic injuries were associated with previously-known regional differences in pediatric TBI mortality,[3,4] we conducted linear regression between these variables and pediatric TBI mortality across the US Census Bureau regions.

We conducted two sensitivity analyses. In the first sensitivity analysis, we included TBI cases with codes that were definite or possible for TBI as defined by the US Military Health System (probable TBI).[17] In the second sensitivity analysis, as a proxy for severe TBI, we included only patients with coding for TBI and the use of invasive mechanical ventilation (IMV) and without a pre-existing complex chronic condition (TBI + IMV), as supplied by PHIS (as PHIS does not include Glasgow Coma Scale score data).[11]

All statistical analyses were performed using RStudio version 1.4.1103 (RStudio, Boston, MA) and R versions 4.0.5 and 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria) with the following packages: caret, cowplot, ggrepel, gifski, kableExtra, knitr, lattice, lubridate, precrec, seastests, splines tidyverse, usmap.

Role of the Funding Source

The funders had no role in study design, data collection, analysis, interpretation, or writing of the report.

Results

Incidence

There were 50,872 encounters among 50,301 patients across 38 hospitals. Cohort demographics are shown in Supplemental Table 1 and stratified by mortality in Table 1. The median (interquartile range [IQR]) age was 5.7 (1.1–12.2) years. The cohort was 63.6% (32,361/50,872) male, 61.8% (31,460/50,872) white, 15.6% (7,961/50,872) black, and 19.9% (10,139/50,872) Hispanic. 19.3% (9,817/50,872) had an underlying complex chronic condition. The median (IQR) 2010 family income was $40,643 ($32,496 – $52,917). TBI admissions significantly decreased over the 10-year study period. There were 5,489 admissions in 2010 compared to 4,933 in 2019, p = 0.039 for trend. GDP-adjusted hospital charges per admission significantly increased over the study period (median [IQR] $17,580.5 [$9,007 – $36,853] in 2010 vs. $24,675 [$14,090 – $48,904] in 2019, p < 0.0001). TBI admissions met criteria for seasonality using Webel and Ollech's method. As shown in Supplemental Figure 1, there was an overall summer-predominance of admissions, with a median (IQR) 504 (480 – 526) in July compared to 344 (326 – 358) in January (p = 0.00018). TBI admissions typically peaked in the afternoon and evening hours, as shown in Supplemental Figure 2.

Mortality

Overall survival to discharge was 97.3% (49,491/50,872). There was a higher percentage of deaths in the winter compared with the summer, though the absolute number of deaths per season was similar (311/10,032 [3.1%] in winter versus 360/14,630 [2.5%] in the summer), shown in Supplemental Figure 1. Survival to discharge did not significantly change over time (5,347/5,489 [97.4%] in 2010 vs. 4,812/4,933 [97.5%] in 2019, p = 0.24). As shown in Figure 1, median family income was inversely related to TBI mortality. Zip-codes with median family income < $20,000 were associated with an overall 3.1% (29/950) mortality, compared with 1.3% (29/2,267) mortality among zip-codes with a median family income greater than $80,000 (p = 0.00096). When stratified according to United States Department of Agriculture RUCA codes, this inverse association between median family income and mortality was present in urban areas and isolated small rural towns, but not in large rural cities or small rural towns, as shown in Supplemental Figure 3. When stratified according to United States Office of Management and Budget race categories, there were significant differences in mortality according to income for patients of white race (3.0% [6/194] for income <$20,000 versus 1.1% [17/1,608] for income >$80,000, p = 0.041), but not for patients of other races, as shown in Supplemental Figure 4.

As shown in Figure 2, there was more than 3-fold difference in TBI mortality across the United States Census Divisions (4.1% in the East South Central Division vs. 1.2% in the Pacific Division, p < 0.0001). Also shown in Figure 2, there was 10-fold difference in TBI mortality at the hospital level (range 0.6%−6.1%, p < 0.0001). The 2010 median income ranged from $33,249 in the East South Central region to $51,964 in the New England region. As shown in Figure 3, regional variation in overall TBI mortality was not significantly associated with 2010 median income (adjusted r-squared 0.20, p = 0.13). The Middle Atlantic region had substantially lower TBI mortality than other regions with similar income. After removing the Middle Atlantic region, median income was inversely associated with TBI mortality (adjusted r-squared 0.66, p = 0.0085, Supplemental Figure 5).

Ballistic Injuries

There were 481/50,872 (0.9%) of TBI admissions with coding for gunshot wound or explosive device. Of these, 397/481 (82.5%) were injured by a firearm, 82/481 (17.0%) were injured by an air gun, and 2/481 (0.4%) were injured by an explosive. As shown in Figure 1, family income was inversely associated with ballistic TBI. Zip-codes with median family income < $20,000 were associated with an overall 2.5% (24/950) ballistic TBI, compared with 0.3% (7/2,267) ballistic TBI among zip-codes with a median family income greater than $80,000 (p < 0.0001).

Compared to the entire TBI cohort, patients with ballistic injuries were older, median (IQR) age 11.1 (4.8–14.7) vs. 5.7 (1.1–12.2), p < 0.0001 (Supplemental Table 1). A significantly higher proportion of patients with ballistic injuries were also male (360/481 [74.8%] vs. 32,361/50,872 [63.6%], p < 0.0001) and of black race (192/481 [39.9%] vs. 7,961/50,872 [15.6%], p < 0.0001). These patients were more frequently admitted to the ICU (363/481 [75.5%] vs. 20,929/50,872 [41.1%], p < 0.0001), more frequently placed on mechanical ventilation (325/481 [67.6%] vs. 10,109/50,872 [19.9%], p < 0.0001), and had lower survival to discharge (362/481 [75.3%] vs. 49,491/50,872 [97.3%], p < 0.0001). Ballistic TBI admissions were associated with higher hospital charges, median (IQR) $101,042 ($43,438-$261,718) vs. $25,344 ($13,241-$51,969), p < 0.0001).

As shown in Figure 4, the regional percentage of ballistic TBI was inversely correlated with the 2010 median income for the region (adjusted r-squared 0.64, p = 0.0061). The Middle Atlantic region had notably lower ballistic TBI than other regions with comparable income. Regional variation in overall TBI mortality was directly associated with the percentage of TBI patients secondary to ballistic injuries (adjusted r-squared 0.59, p = 0.0097, Figure 5). The Middle Atlantic Region had mortality consistent with other regions with low proportions of ballistic TBI.

Ballistic TBI admissions did not meet the criteria for seasonality using Webel and Ollech's method. The number of ballistic TBI admissions did not significantly change over time (Supplemental Figure 6, 44 in 2010 versus 56 in 2019, p = 0.26). The percentage of TBI patients secondary to ballistic injuries ranged from 0.3% in the New England region to 2% in the East South Central region.

Modeling

A multivariable logistic regression model to elucidate factors associated with pediatric TBI mortality is shown in Table 2. The linearity assumption for family income is shown in Supplemental Figure 7. The spline relationship between age and mortality is shown in Supplemental Figure 8. After adjustment, lower median family income was significantly associated with pediatric TBI mortality (odds ratio 0.94, 95% CI 0.90 – 0.98 for every $10,000 of family income). Ballistic injury was also significantly associated with mortality (odds ratio 5.19, 95% CI 4.00 – 6.73). Regional variation in TBI mortality remained significant, with patients in the East South Central United States having an odds ratio (95% CI) of mortality of 2.09 (1.61 – 2.71) compared to patients in the Pacific region.

Sensitivity Analyses: Probable TBI and TBI + IMV

The demographics for the sensitivity analyses including patients with probable TBI and restricting the cohort to TBI patients undergoing invasive mechanical ventilation (TBI + IMV) are shown in Supplemental Table 1 and stratified by mortality in Supplemental Table 2 and Supplemental Table 3, respectively. Regional- and hospital-level variation for these sensitivity analyses is shown in Supplemental Figure 9 for the probable TBI group and Supplemental Figure 10 for the TBI + IMV group. Multivariable logistic regression for factors associated with mortality in the probable TBI group is shown in Supplemental Table 4 and in the TBI + IMV group is shown in Supplemental Table 5. Briefly, median family income was inversely associated with mortality in the Probable TBI cohort (OR 0.94, 95% CI 0.90–0.98 per $10,000), the point estimate was similar in the smaller TBI + IMV cohort, but the association did not reach statistical significance (OR 0.95, 95% CI 0.87–1.05 per $10,000). Ballistic injury was significantly associated with mortality in both cohorts (Probable TBI OR 5.38, 95% CI 4.16–6.96, TBI + IMV OR 10.68, 95% CI 6.45–17.70).

Discussion

This study reports the novel finding that zip-code level income is associated with pediatric TBI mortality in the United States. While previous studies have come to conflicting conclusions concerning the association between socioeconomic status and pediatric trauma outcomes,[9,10] the present study is in agreement with adult data showing lower income zip-codes have higher in-hospital trauma mortality.[26] Figure 1 shows that ballistic injuries increased significantly in zip-codes with the lowest 2010 median family incomes. Zip-codes with a 2010 median household income less than $40,000 had a 36% higher pediatric TBI mortality rate than those with a median income greater than $40,000. In multivariable logistic regression analysis, every $10,000 of family income was associated with an odds ratio of mortality of 0.94 (Table 2). In an additional novel analysis, this mortality difference was especially notable in areas classified as "urban" by RUCA codes, as shown in Supplemental Figure 3, arguing that associations between income and mortality do not simply mirror distance to trauma centres.[7,8,26] While the point-estimate was similar, the association between income and mortality was not significant in the sensitivity analysis of patients receiving invasive mechanical ventilation (Supplemental Table 5). It is unclear whether this represents true differences in care-seeking patterns or is due to reduced power or possible model overfitting, as this cohort was only 10.3% of the size of the main analysis. Additionally, the association between income and mortality was present among patients of white race, but not other United States Office of Management and Budget race categories (Supplemental Figure 4). Further work is needed to understand whether this represents differences in care-seeking patterns or TBI mechanisms among these populations, or reflects structural racism.[27–29]

Ballistic TBI (82% of which was caused by firearms) represents a small, but particularly severe phenotype. This finding is in keeping with recently published trauma literature.[30] While representing less than 1% of pediatric TBI, these patients were nearly nine times more likely to die than the overall cohort. A public health intervention aimed at reducing firearm-related TBI in children[31] could also reduce pediatric TBI mortality. Given the disproportionate incidence and associated increased mortality of ballistic TBI in communities with lower household-level income (Figure 1), such an intervention would also align with the American Academy of Pediatrics' goals of reducing health disparities.[32] Interestingly, while overall rates of pediatric TBI decreased in the database between 2010–2019, ballistic TBIs did not (Supplemental Figure 6). In some states, physicians have been restricted from inquiring about gun ownership and offering counselling on safe gun storage for children.[33,34] Our data suggest that this may undermine physician efforts to reduce mortality in pediatric TBI.

The present study also offers insight into regional differences in pediatric TBI mortality. As in previous studies, we found a greater than three-fold difference in TBI mortality across the US Census Divisions (Figure 2).[3–5] Previous work has shown these differences to persist after adjustment for hospital characteristics.[5] We demonstrate that this difference is robust to adjustment for sociodemographic factors (e.g. age, sex, RUCA codes). Notably, we also show correlations between income, ballistic TBI, and TBI mortality (Figures 3–5). Taken together, these trends suggest that actions to reduce poverty and prevent ballistic injuries may reduce disparities in pediatric TBI mortality.

Caution is needed when interpreting the meaning of these findings. While the present study identified ten-fold interhospital variation in TBI mortality,[35] it does not necessarily imply discrepancies in inpatient care. Previous work has noted disparities in pediatric TBI mortality persist after adjustment for hospital characteristics.[5] While the practice patterns of high-performing centres should be analyzed as part of a positive-deviance approach to quality improvement,[36] survival in TBI is dependent upon a complex chain of healthcare delivery. Many previous studies have demonstrated that rapid access to pediatric trauma centres reduces mortality.[7,8,37–40] While we did perform multivariable adjustment for RUCA codes, we were unable to precisely determine important factors such as transport time, which may be more important in improving pediatric TBI mortality than changes to inpatient practice. Studies from developing nations have shown that improving first-responder care in underserved areas can reduce trauma mortality.[41] Additional analyses, including more granular data and additional, non-children's hospital trauma centres, are needed before designing public health interventions.

Our study also shows the seasonality of pediatric TBI, with greater incidence in the summer, but stable absolute mortality, as shown in Supplemental Figure 1. Despite the differing mechanisms, the overall summer predominance of TBI is similar to that for trauma overall.[15,42] This summer-predominant seasonality of TBI is likely a reflection of seasonal changes in recreational behaviour, as sports represent a significant aetiology of pediatric TBI.[3,6] The summertime increase in overall incidence coupled with no change in absolute mortality seen in Supplemental Figure 1 may suggest that there is an increase in milder sports-related TBI during the warmer months. Another likely cause of increased incidence of TBI in the summer and spring is increased automobile traffic during these months,[43] as automobile accidents are a predominant cause of pediatric TBI.[3,6]

This study has several limitations. While including over 50,000 encounters from 38 hospitals across the US, these data may not be fully representative of the US pediatric population. The median income of the included sample was $40,643, compared favourably to a nationwide average of $49,445 in 2010.[44] However, PHIS predominantly includes large children's hospitals, many of which are dedicated pediatric trauma centres. Because access to pediatric trauma care has previously been shown to reduce mortality,[7,8] the present study may underestimate mortality rates among children hospitalized with TBI. Pediatric trauma care is known to be inconsistently structured across the United States, and the distance to trauma care is related to mortality.[26,45] Because income data, but not geocoded zip-code data, are available in PHIS, it was not possible to conduct an analysis regarding the distance between a patient's home and care center. We attempted to account for this relationship through the use of RUCA codes, but recognize that a geocoding approach would have been more precise. Though PHIS is quality controlled,[11] all database analysis is subject to misclassification bias from errors in diagnostic coding. Additionally, we were unable to completely discern the factors contributing to mortality for each TBI. We attempted to adjust for the intrinsic heterogeneity of TBI by classifying diagnoses according to type (e.g. concussion versus subarachnoid haemorrhage), but this approach is limited in its granularity. While we excluded subsequent encounters for the same injury based on ICD codes, approximately 1% of patients had more than one TBI encounter. The clinical information in PHIS is limited, thus we could not fully control for severity of illness when assessing interhospital variability in mortality. Lastly, though using IMV is commonly used as a surrogate for severe TBI, it is imperfect.[46]

In conclusion, lower family income and ballistic TBI are associated with pediatric TBI mortality in the United States. These associations are significant after multivariable adjustment for a variety of confounders. Pediatric TBI mortality varies three-fold regionally, and ten-fold across hospitals in the PHIS database. This variability is correlated with regional income and rates of ballistic TBI. Further work is needed to develop targeted interventions to address these disparities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

95% CI	Ninety-five Percent Confidence Interval
CCC	Complex Chronic Condition
CHA	Children’s Hospital Association
CMS	Centers for Medicare & Medicaid Services
GDP	Gross Domestic Product
ICD	International Classification of Diseases
IMV	Invasive Mechanical Ventilation
IQR	Interquartile Range
LOESS	LOcally Estimated Scatterplot Smoothing
PHIS	Pediatric Health Information Systems
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TBI	Traumatic Brain Injury

TBI + IMV	Traumatic Brain Injury Patients Receiving Invasive Mechanical Ventilation
US	United States

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Research in context

Evidence before this study

Mortality in pediatric traumatic brain injury (TBI) varies across the United States (US), with more rural areas and the Southeastern US experiencing higher mortality. However, it is unclear whether these differences are related to differences in TBI mechanisms, pre-hospital care, trauma care, or sociodemographic factors.

Added value of this study

For the first time, this study demonstrates an association between median family income (assessed at the zip-code level) and pediatric TBI mortality in the United States. This association between income and TBI mortality was present when stratified according to rural / urban status, and in multivariable logistic regression after adjustment for confounders. A second association between the proportion of ballistic (predominantly firearm) TBI and mortality was also demonstrated. On a regional basis, higher levels of ballistic TBI were linearly associated with increases in TBI mortality.

Implications of all the available evidence

Median family income and ballistic injuries are associated with pediatric TBI mortality. Further research is necessary to determine whether interventions to reduce poverty and firearm violence may reduce pediatric TBI mortality.

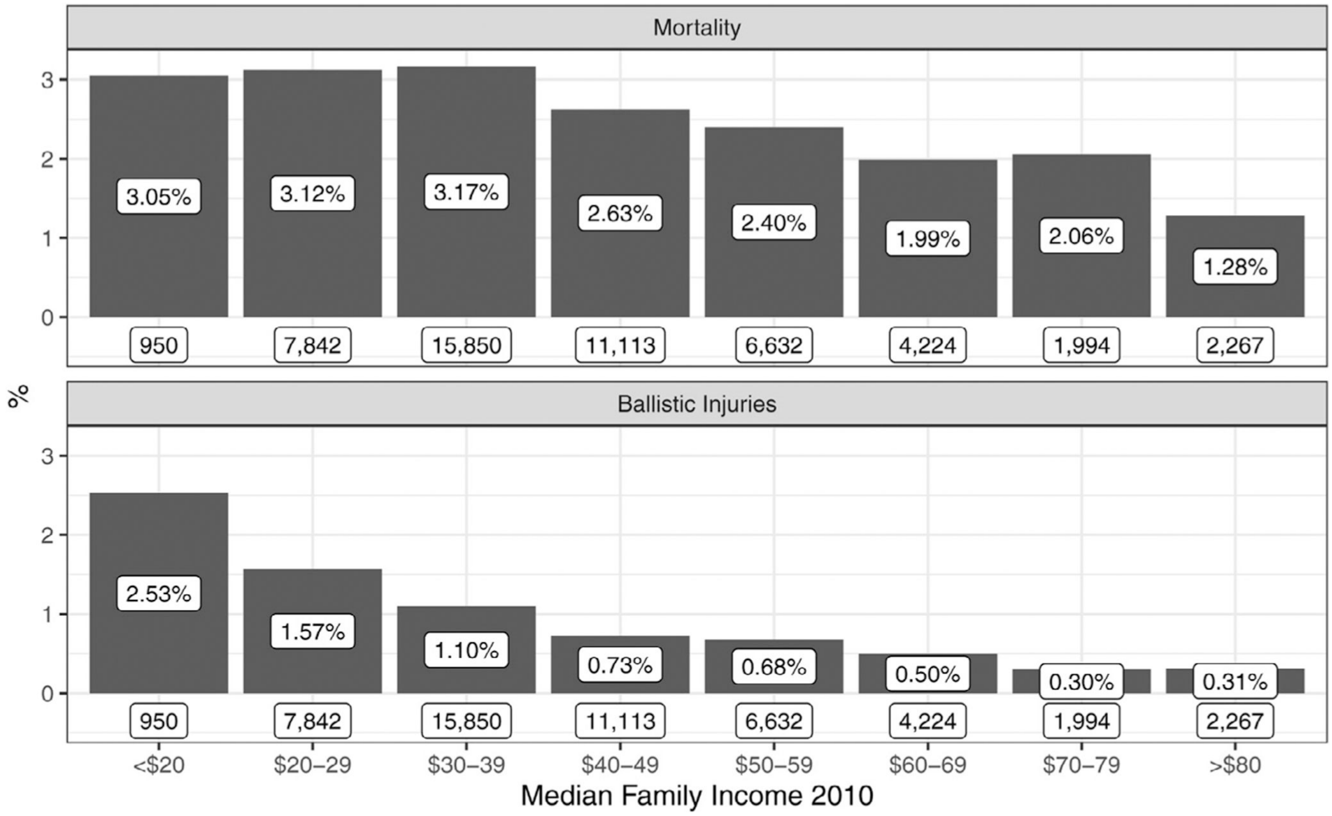

Figure 1.

TBI and 2010 Median Family Income. The top panel shows the association between the 2010 median family income for the patient's zip code on the x-axis and the % of TBI injuries caused by ballistic injuries (predominantly firearms) on the y-axis. The bottom panel shows the association between the 2010 median family income on the x-axis and the % TBI mortality on the y-axis. For both panels, income is binned by $10,000 increments, and the number underneath each bar represents the number of encounters per bin.

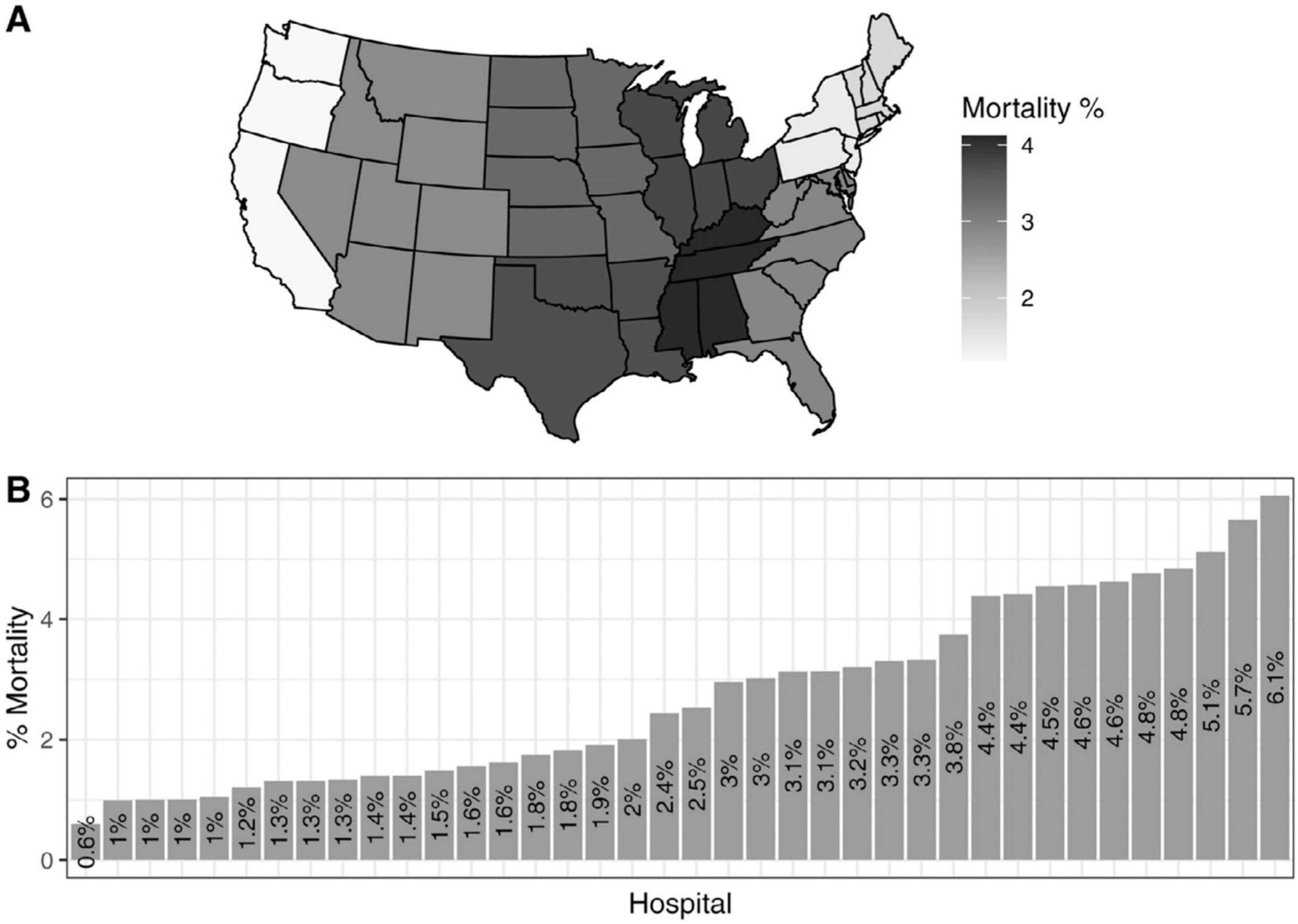

Figure 2.

Variation in TBI Mortality. Panel A shows hospitals represented according to their US Census region. Alaska and Hawaii were excluded as there are no PHIS member hospitals in those states. For each region, the mortality is normalized to the total number of admissions in that region and expressed as a percentage according to the scale on the right. Panel B is a barplot of TBI Mortality by Hospital. Individual hospitals are displayed on the x-axis, with % of TBI mortality on the y-axis. The numbers within the bars represent the average mortality at that hospital over the 10-year study period.

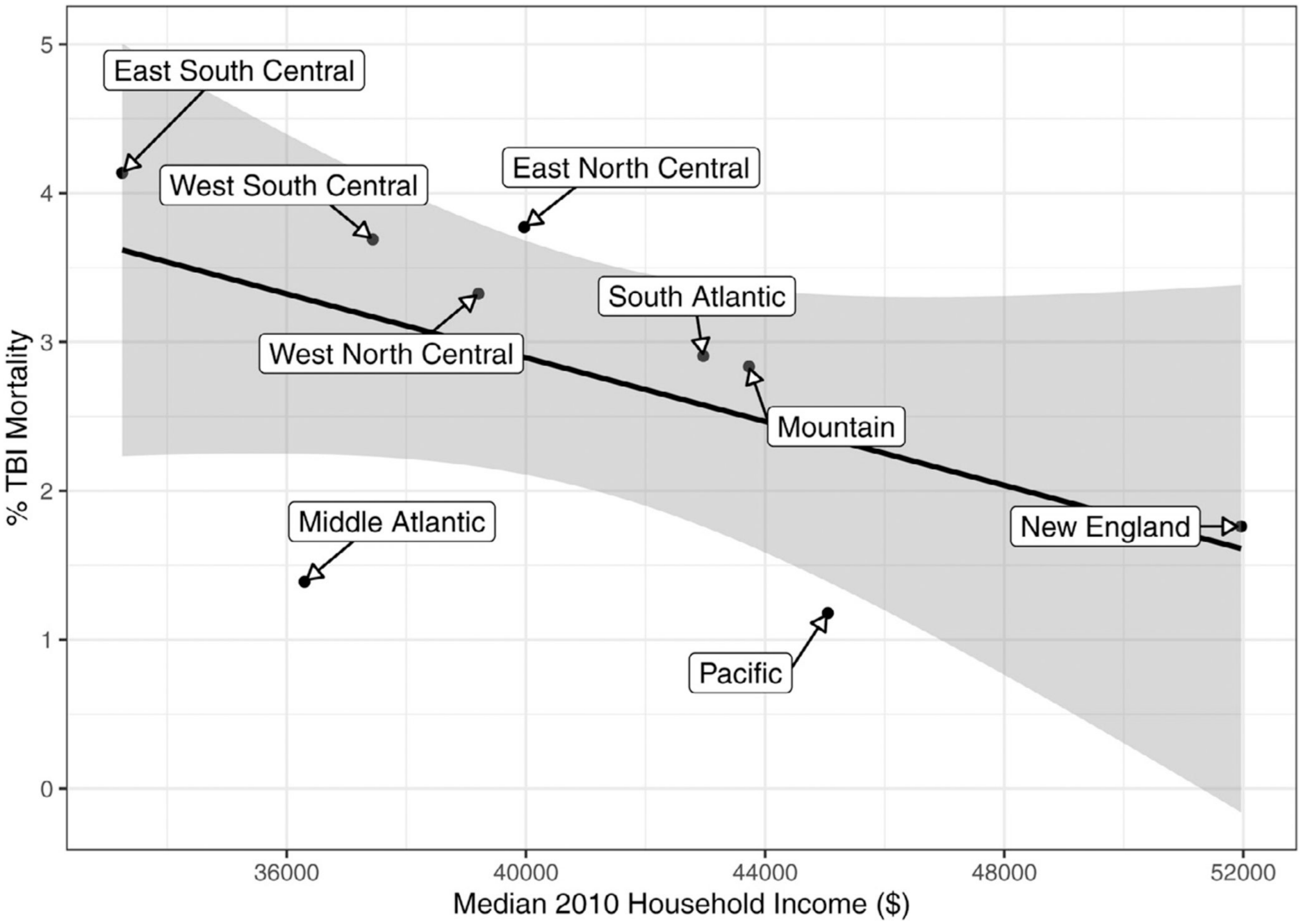

Figure 3.

Correlation between regional median household income and % TBI mortality. The 2010 median family income for the patient's zip code (grouped by US Census Division) is plotted on the x-axis and the % TBI mortality is plotted on the y-axis. The solid line represents the line of best fit using linear regression. The gray shaded region represents the 95% confidence interval of the model.

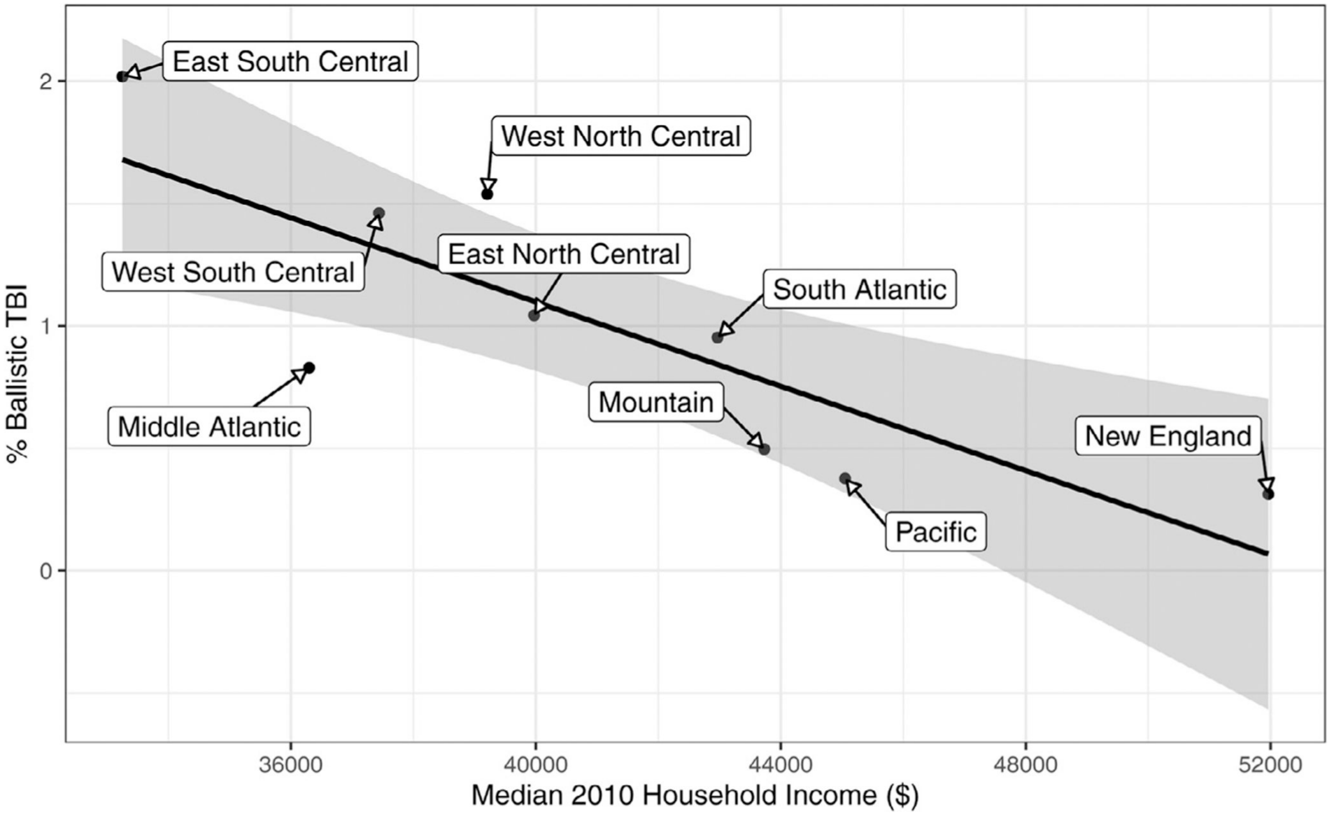

Figure 4.

Correlation between regional median household income and % ballistic TBI. The 2010 median family income for the patient's zip code (grouped by US Census Division) is plotted on the x-axis and the % ballistic TBI is plotted on the y-axis. The solid line represents the line of best fit using linear regression. The gray shaded region represents the 95% confidence interval of the model.

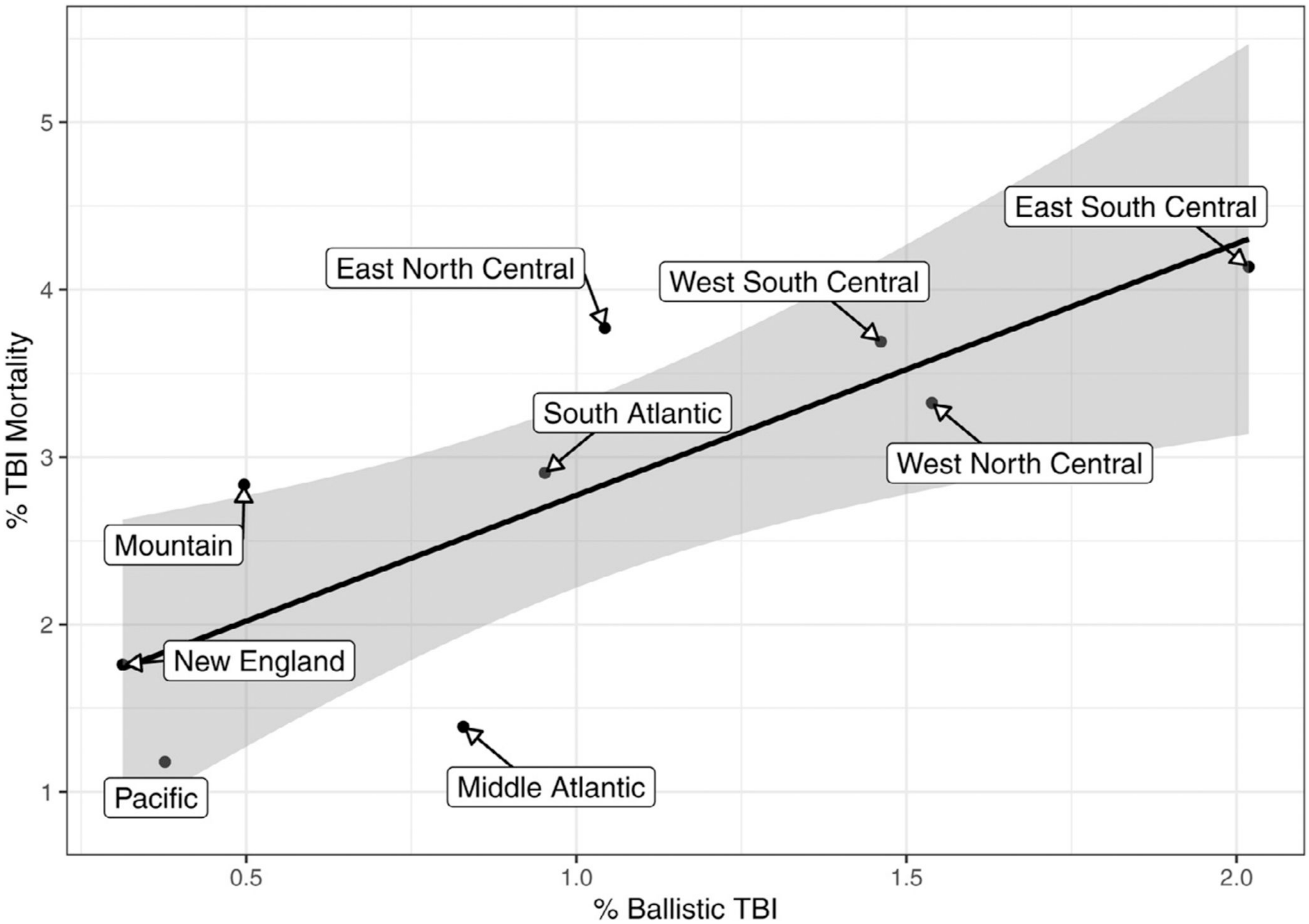

Figure 5.

Correlation between % ballistic TBI and % TBI mortality. The % ballistic TBI (grouped by US Census Division) is plotted on the x-axis and the % TBI mortality is plotted on the y-axis. The solid line represents the line of best fit using linear regression. The gray shaded region represents the 95% confidence interval of the model.

Table 1:

Cohort Demographics.

Characteristic	Overall, N = 50,872	Survived, N = 49,491	Died, N = 1,381	p-value
Age (Years)	5.7 (1.1, 12.2)	5.7 (1.1, 12.2)	6.3 (1.8, 12.5)	0.00067
Sex				0.48
Female	18,511	17,996 (97.2%)	515 (2.8%)	
Male	32,361	31,495 (97.3%)	866 (2.7%)	
Race				<0.0001
White	31,460	30,695 (97.6%)	765 (2.4%)	
Black	7,961	7,668 (96.3%)	293 (3.7%)	
American Indian	586	572 (97.6%)	14 (2.4%)	
Asian	1,313	1,295 (98.6%)	18 (1.4%)	
Pacific Islander	161	159 (98.8%)	2 (1.2%)	
Other	9,391	9,102 (96.9%)	289 (3.1%)	
Ethnicity				<0.0001
Hispanic or Latino	10,139	9,945 (98.1%)	194 (1.9%)	
Not Hispanic or Latino	35,934	34,984 (97.4%)	950 (2.6%)	
Unknown	4,799	4,562 (95.1%)	237 (4.9%)	
Zip-Code Median Income (S)	40,643 (32,496, 52,917)	40,694 (32,516, 53,077)	37,799 (31,217, 48,962)	<0.0001
Any Complex Chronic Condition (CCC)	9,817	8,726 (88.9%)	1,091 (11.1%)	<0.0001
Ballistic Injury	481	362 (75.3%)	119 (24.7%)	<0.0001
Rural Urban Commuter Code				<0.0001
Urban	41,910	40,839 (97.4%)	1,071 (2.6%)	
Large Rural City	4,461	4,315 (96.7%)	146 (3.3%)	
Small Rural Town	2,644	2,553 (96.6%)	91 (3.4%)	
Isolated Small Rural Town	1,857	1,784 (96.1%)	73 (3.9%)	
US Census Region				<0.0001
East North Central	6,710	6,457 (96.2%)	253 (3.8%)	
East South Central	5,004	4,797 (95.9%)	207 (4.1%)	
Middle Atlantic	4,102	4,045 (98.6%)	57 (1.4%)	
Mountain	6,843	6,649 (97.2%)	194 (2.8%)	
New England	2,556	2,511 (98.2%)	45 (1.8%)	

Characteristic	Overall, N = 50,872	Survived, N = 49,491	Died, N = 1,381	p-value
Pacific	10,347	10,225 (98.8%)	122 (1.2%)	
South Atlantic	6,195	6,015 (97.1%)	180 (2.9%)	
West North Central	3,640	3,519 (96.7%)	121 (3.3%)	
West South Central	5,475	5,273 (96.3%)	202 (3.7%)	
Admission Season				0.023
Spring	13,323	12,969 (97.3%)	354 (2.7%)	
Summer	14,630	14,270 (97.5%)	360 (2.5%)	
Autumn	12,887	12,531 (97.2%)	356 (2.8%)	
Winter	10,032	9,721 (96.9%)	311 (3.1%)	
Admission Diagnosis				<0.0001
Concussion	7,030	7,027 (100.0%)	3 (0.0%)	
Skull Fracture	15,683	15,605 (99.5%)	78 (0.5%)	
Skull Fracture + Hemorrhage	11,969	11,562 (96.6%)	407 (3.4%)	
Artery or Nerve Injury	44	44 (100.0%)	0 (0.0%)	
Epidural	2,416	2,406 (99.6%)	10 (0.4%)	
Subdural	7,839	7,405 (94.5%)	434 (5.5%)	
Subarachnoid	1,226	1,156 (94.3%)	70 (5.7%)	
Intracerebral Hemorrhage	464	432 (93.1%)	32 (6.9%)	
Unspecified Intracranial Hemorrhage	655	632 (96.5%)	23 (3.5%)	
Contusion / Laceration	1,243	1,174 (94.4%)	69 (5.6%)	
Diffuse Axonal Injury	724	639 (88.3%)	85 (11.7%)	
Cerebral Edema	160	82 (51.2%)	78 (48.8%)	
Unspecified Injury	1,419	1,327 (93.5%)	92 (6.5%)	
Admitted to ICU	20,929	19,707 (94.2%)	1,222 (5.8%)	<0.0001
Hospital Length of Stay (days)	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	0.031
Hospital Charges ($)	25,344 (13,240, 51,969)	24,604 (12,972, 49,533)	89,688 (48,898, 152,143)	<0.0001
Unknown	176	171	5	

Table 2:

Multivariable Logistic Regression for Factors Associated with Mortality in Pediatric TBI.

Variable	OR	p-value
Income		
Median Family Income (per $10,000)	0.94 (0.90 – 0.98)	0.0061
Age (Years)		
Modeled as a Cubic Spline, Shown in Supplemental Figure 6		0.00092
Race (Reference: White)		
Race: Black	1.08 (0.91 – 1.27)	0.39
Race: American Indian	1.00 (0.55 – 1.79)	0.99
Race: Asian	0.76 (0.46 – 1.25)	0.28
Race: Pacific Islander	0.46 (0.11 – 1.94)	0.29
Race: Other	1.43 (1.2 – 1.69)	<0.0001
Ethnicity (Reference: Not Hispanic)		
Ethnicity: Hispanic or Latino	0.73 (0.6 – 0.88)	0.00094
Ethnicity: Unknown	1.65 (1.38 – 1.98)	<0.0001
Sex (Reference: Female)		
Sex: Male	0.88 (0.78 – 0.99)	0.040
Rural Urban Commuter Code (Reference: Urban)		
Rural Urban Commuter Code: Large Rural City	0.95 (0.78 – 1.17)	0.65
Rural Urban Commuter Code: Small Rural Town	0.92 (0.72 – 1.18)	0.52
Rural Urban Commuter Code: Isolated Small Rural Town	1.05 (0.8 – 1.39)	0.72
Complex Chronic Condition (Reference: No Complex Chronic Condition)		
Pre-existing Complex Chronic Condition	11.97 (10.43 – 13.73)	<0.0001
Ballistic Injury (Reference: No Ballistic Injury)		
Ballistic Injury	5.21 (4.01 – 6.77)	<0.0001
US Census Division (Reference: Pacific)		
US Census Subregion: Mountain	1.58 (1.23 – 2.03)	0.00037
US Census Subregion: West North Central	1.67 (1.25 – 2.22)	0.00048
US Census Subregion: West South Central	1.78 (1.39 – 2.29)	<0.0001
US Census Subregion: East North Central	1.87 (1.46 – 2.39)	<0.0001
US Census Subregion: East South Central	1.78 (1.36 – 2.33)	<0.0001

Variable	OR	p-value
US Census Subregion: New England	1.25 (0.87 – 1.81)	0.23
US Census Subregion: Middle Atlantic	0.83 (0.59 – 1.17)	0.29
US Census Subregion: South Atlantic	1.43 (1.1 – 1.85)	0.0068
Admit Season (Reference: Summer)		
Admit Season: Spring	1.10 (0.94 – 1.29)	0.24
Admit Season: Autumn	1.15 (0.98 – 1.36)	0.082
Admit Season: Winter	1.29 (1.09 – 1.53)	0.0028
Admission Dx (Reference: Concussion)		
Admission Dx: Skull Fracture without ICH	8.09 (2.55 – 25.7)	0.00039
Admission Dx: Skull Fracture with ICH	52.49 (16.81 – 163.91)	<0.0001
Admission Dx: Cranial Nerve or Carotid Artery Injury	0.00 (0 - Inf)	0.95
Admission Dx: Epidural Hemorrhage	5.53 (1.52 – 20.18)	0.0096
Admission Dx: Subdural Hemorrhage	60.66 (19.41 – 189.53)	<0.0001
Admission Dx: Subarachnoid Hemorrhage	87.31 (27.29 – 279.3)	<0.0001
Admission Dx: Intracerebral / Intracerebellar Hemorrhage	47.46 (14.3 – 157.52)	<0.0001
Admission Dx: Unspecified Intracranial Hemorrhage	42.48 (12.62 – 142.96)	<0.0001
Admission Dx: Cerebral / Cerebellar Contusion or Laceration	60.61 (18.88 – 194.57)	<0.0001
Admission Dx: Diffuse Axonal Injury	97.46 (30.55 – 310.91)	<0.0001
Admission Dx: Traumatic Cerebral Edema	527.03 (160.53 – 1730.25)	<0.0001
Admission Dx: Unspecified Injury	92.46 (29.1 – 293.8)	<0.0001