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Correlation Between Various Mechanisms of Injury and Clinical Outcomes in Patients with Severe Traumatic Brain Injury (TBI)

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Abstract

Background: Traumatic Brain Injury (TBI) is a major public health concern as global incidence continues to increase, often resulting in chronic health issues. Clinical outcomes following TBI are strongly influenced by a variety of sociodemographic factors, but the role of the primary mechanism of injury is not as well understood. This study aimed to assess the relationship between the mechanism of injury and clinical outcomes to improve future care for patients with severe TBI. **Methods:** We conducted a retrospective review at a Level 1 Trauma Center in Queens, New York. Patients with AIS Head ≥3 and severe TBI (Glasgow Coma Scale [GCS] ≤8 after resuscitation but before sedation) admitted between January 2020 and December 2023 were included (N = 1,124). Primary mechanism of injury was categorized as Falls, Assault, Transport-related, Struck-by/Hit by Object, Self-harm, and Other/Miscellaneous. These categories were compared against demographic characteristics, severity scales (AIS Head, Injury Severity Score [ISS], and GCS), trauma type (blunt vs. penetrating), and clinical outcomes including Emergency Department (ED) length of stay (LOS, hours), hospital LOS (days), intensive care unit (ICU) LOS (days), ventilator days, and discharge disposition (Alive vs. Died). Statistical comparisons were performed using ANOVA, the Kruskal–Wallis test, the Mann–Whitney U test, and the Chi-square test, with significance set at $p < 0.05$. **Results:** Our study included 1,124 patients (23.8% female). We observed significant between-group differences when comparing primary injury mechanism to severity scales, with the worst outcomes within the self-harm group (p<0.001; GCS=4.64, AIS Head=4.41, ISS=39.73). Significant between-group differences were also seen for ED and hospital LOS and number of days on mechanical ventilation (p<0.01), with the primary mechanism of injury category "other/miscellaneous" requiring the longest average hospital LOS (27.6 days) and ED LOS (18.5 hours). Penetrating injuries had significantly higher ISS (p<0.001) and lower GCS (p<0.001) scores than blunt injuries, and required a substantially greater number of vent days (p<0.01). **Conclusion:** In agreement with existing literature, falls were the most common cause of TBI in our cohort. Penetrating injuries resulted in worse outcomes, with the greatest mortality seen among patients whose injuries were self-inflicted.

Keywords: traumatic brain injury; mechanism of injury; injury severity; length of stay; ventilator days

Introduction

Traumatic brain injury (TBI) is caused by an outside force, such as a bump, blow, or jolt to the head or body. It can be non-penetrating (blunt) or penetrating. Non-penetrating TBIs are caused by an external force strong enough to move the brain within the skull. These can include falls, motor vehicle collisions (MVC), sports injuries, blast injury, or being struck by an object. Penetrating injuries are less common but often more severe, and occur when an object, such as a bullet, pierces the skull and enters the brain tissue [1]. Furthermore, TBI can be classified as mild, moderate, or severe. Mild TBI, or concussion, involves normal structural imaging, loss of consciousness for <30 minutes, alteration of mental state for no more than 24 hours, no more than one day of post-traumatic amnesia, and a Glasgow Coma Scale (GCS) of 13-15. Moderate to severe TBI involves normal or abnormal structural imaging, at least 30 minutes of loss of consciousness, >24 hours of altered mental state and post-traumatic amnesia, and a GCS as low as 3 [2].

The CDC reports there were approximately 214,110 TBI-related hospitalizations in 2020 and 69,473 TBI-related deaths in the United States in 2021 [3]. However, it is well understood that nearly all estimates of TBI are undercounts. This is partly due to the disproportionate amount of TBI deaths that occur outside of the healthcare setting, such as those due to MVC or falls. Globally, underestimates are far greater, as the WHO states that approximately two-thirds of all global TBI-related deaths are not counted [4].

Males are nearly two times more likely to be hospitalized for TBI and three times more likely to die from a TBI than females [3]. It is important to note that there are no national prevalence estimates for TBI due to intimate partner violence, yet studies in shelters and EDs have reported that 30-74% of women who experience intimate partner violence have a history of TBI [5]. Sex-related differences in outcomes following TBI are less well understood. One 2019 scoping review reported that human studies generally report worse outcomes in women with TBI than men, while animal studies report the opposite [6]. When stratifying by TBI severity, women experiencing moderate to severe TBI are more likely to have better outcomes than men with moderate to severe TBI, while women experiencing mild TBI are more likely to have worse outcomes in clinical studies with mixed results in animal studies [6]. Recently, animal studies have explored the role of sex hormones in recovery following TBI. A 2018 review by *Späni et. al* noted that estrogen and progesterone contribute to sex differences in outcomes following TBI [7]. Female sex hormones (namely, estrogen and progesterone) play a role in attenuating neuroinflammation and reducing cerebral edema [7].

People aged 75 years and older account for about 32% of TBI-related hospitalizations and 28% of TBI-related deaths [3]. A study evaluating mortality trends from 1999 to 2020 using the CDC Wide-Ranging Online Data for Epidemiologic Research (WONDER) database reported that patients 85 years and older had the highest age-adjusted mortality rate, followed closely by the 75–84-year-old age group [8]. American Indian or Alaska Native adults have the highest age-adjusted mortality rate [8,9]. Further, African American and Hispanic patients have a lower risk of in-hospital mortality, but longer hospital length of stay and lower likelihood of being discharged to a rehabilitation facility when compared to White patients [10]. African American patients are also significantly more likely to incur a TBI from violence when compared with non-Hispanic White patients. Minorities are significantly more likely to have worse functional outcomes compared with non-Hispanic White patients [9].

Falls have consistently remained the leading cause of TBI, followed by injuries due to MVC, interpersonal violence, and exposure to mechanical forces [11]. A large population-based study assessing regional, national, and global differences in TBI burden reported that most countries report falls as the leading cause of both mild and moderate to severe TBI [12]. However, there is a significant difference in the cause by age group. While falls remain the primary cause of all TBI severities in older adults (65 years and up), motor vehicle-related injuries contribute more to mild TBI in young adults (20-39 years old), and violent events such as penetrating injuries by firearm or sharp objects – including self-harm – contribute more to moderate to severe TBI in young adults [12]. Suicide is a

leading cause of TBI-related death in individuals aged 15-64 years old, and nearly all such deaths are due to firearm-related injury [13,14].

Mechanism of injury is closely linked to clinical outcomes following TBI, but largely influenced by sociodemographic factors such as sex, age, and race [10,15-17]. Additionally, the global incidence of TBI has continued to increase [18] and is associated with a substantial burden, as TBI often persists as a chronic disease [19]. Thus, it is becoming increasingly important to understand the complex interplay between the factors influencing TBI and healthcare outcomes. While the various causes of TBI are well studied, the primary mechanism of injury as an independent predictor of post-TBI clinical outcomes is not. This study aimed to assess this relationship to improve future care for patients with severe TBI.

Methods

Study Design

We performed a single-center, retrospective cohort study at Elmhurst Hospital Center, a Level 1 trauma center verified by the American College of Surgeons (ACS) in Queens, New York City. Patient data were obtained from the National Trauma Registry of the ACS (NTRACS) database for our center. The study period included all patients presenting between January 1, 2020, and December 31, 2023.

Study Population

Patients were eligible if they sustained a traumatic brain injury (TBI) with a head Abbreviated Injury Severity (AIS) score ≥3. Severe TBI was further defined as a Glasgow Coma Scale (GCS) score of 8 or less after resuscitation but before sedation. A total of 1,124 patients met the inclusion criteria.

Variables

The primary independent variable was mechanism of injury, categorized as: Falls, Assault, Transport-related injuries (motor vehicle collisions [MVC] and non-motorized transport combined), Struck-by/Hit by Object, Self-harm, and Other/Miscellaneous. For each patient, demographic variables (age, sex, race/ethnicity) were extracted. Trauma severity indicators included AIS Head, Injury Severity Score (ISS), and GCS. Trauma type was classified as blunt or penetrating. Clinical outcomes included emergency department length of stay (ED LOS, hours), hospital length of stay (LOS, days), intensive care unit length of stay (ICU LOS, days), ventilator days, and discharge disposition (Alive vs. Died).

Statistical Analysis

Continuous variables were first tested for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene's test. When assumptions were satisfied, comparisons across mechanisms of injury were performed using one-way analysis of variance (ANOVA); Welch's ANOVA was used when variances were unequal. If assumptions were violated, the Kruskal–Wallis test was applied, followed by Dunn's post-hoc test with Holm adjustment for multiple comparisons. For two-group comparisons (Blunt vs. Penetrating trauma), continuous outcomes were assessed using the Mann–Whitney U test. Categorical outcomes, including discharge status (Alive vs. Died) and trauma type (Blunt vs. Penetrating), were analyzed with Pearson's Chi-square test. Fisher's exact test was applied where expected counts were <5. Effect sizes were reported as η^2/ε^2 for ANOVA/Kruskal–Wallis, Cramer's V for Chi-square tests, and rank-biserial correlation for Mann–Whitney U tests. Missing data were handled with listwise deletion. Given the very small sample sizes in the Struck-by/Hit by Object (n=8) and Other/Miscellaneous (n=12) categories, results for these groups were interpreted with caution. All tests were two-tailed, with statistical significance set at p <

0.05. Analyses were performed using R (v4.3.2), and Microsoft Excel was used for preliminary data management.

Results

1,124 patients (23.8% female) were included in our analysis. The average age and weight for male patients were 48.9 years and 91.3 kg, respectively. The average age and weight for female patients were 64.4 years and 75.3 kg, respectively (Table 1).

Table 1. Demographic and Biometric Characteristics.

Demographic and Biometric Characteristics	Age (years)		Weight (kg)	
	Count	Mean	Mean	Std Dev
Sex				
Female	268	64.38	75.29	37.22
Male	856	48.88	91.30	42.72
Race				
American Indian	1	22.32	96.00	n/a
Asian	169	61.50	73.49	32.67
Black	88	56.66	103.62	54.23
Native Hawaiian or Other Pacific Islander	5	63.57	75.20	44.57
Other	640	48.14	86.77	40.28
White	199	58.29	94.13	44.73
Unknown	22	44.23	83.71	38.46
Ethnicity				
Hispanic	520	46.79	87.69	42.11
Non-Hispanic	558	58.49	86.77	41.84
Unknown	46	46.27	92.00	43.41

Table 1: Demographic and biometric characteristics of the study group. Analysis included 1,124 patients (N=268, 23.8% female). The most common race was "other" (N=640, 56.9%), followed by "White" (N=199, 17.7%). The most common ethnicity was non-Hispanic (N=558, 49.6%). The mean age and weight of female patients were 64.38 years and 75.29 kg, respectively. The mean age and weight of male patients were 48.88 years and 91.30 kg, respectively.

Data on primary mechanism of injury, injury type (blunt vs. penetrating; Table 2), and injury severity (as measured by GCS, AIS head, and ISS scores; Table 3) were recorded. Most of the patients included in the analysis suffered blunt trauma (N=1099, 97.8%), with the most common cause being falls (N=665, 60.5%) and transport-related injuries (N=276, 25.1%). A much smaller proportion of patients suffered penetrating injury (N=25, 2.2%), the most common cause being assault (N=19, 76%), followed by self-harm (N=5, 20%). Mean GCS score for all patients was 12.6, mean AIS Head score for all patients was 3.7, and mean ISS score for all patients was 18.7. Patients whose primary mechanism of injury was self-harm were observed to have the most critical injury severity values (GCS=4.6, AIS Head=4.4, ISS=39.7). Both Kruskal-Wallis and ANOVA testing showed significant

between-group differences when comparing primary mechanism type to injury severity scales (p<0.001).

Table 2. Primary Mechanism of Injury and Trauma Type.

Primary Mechanism	Trauma Type		
	Blunt	Penetrating	Total
Self-harm	17	5	22
Assault	121	19	140
Falls	665	1	666
Struck by / Hit by Object	8	0	8
Other / Miscellaneous	12	0	12
Transport-related injuries (MVC + Non-motorized Transport combined)	276	0	276
Total	**1099**	**25**	**1124**

Table 2: Primary mechanism of injury compared to trauma type. Most trauma recorded was "blunt" (N=1099, 97.8%). The most common mechanism of injury for blunt trauma was "falls" (N=665, 60.5%), followed by "transport-related injuries" (N=276, 25.1%). The most common mechanism of injury for penetrating trauma was "assault" (N=19, 76%), followed by "self-harm" (N=5, 20%). Abbreviations: MVC = Motor Vehicle Collision.

Table 3. Primary Mechanism of Injury and Severity.

Primary Mechanism	GCS (mean ± SD)	AIS Head (mean ± SD)	ISS (mean ± SD)
Assault	12.67 ± 4.15	3.7 ± 0.8	17.44 ± 6.99
Falls	13.26 ± 3.45	3.74 ± 0.82	16.71 ± 7.69
Other / Miscellaneous	12.58 ± 3.06	3.25 ± 0.62	14.75 ± 8.37
Self-harm	4.64 ± 4.22	4.41 ± 0.91	39.73 ± 16.99
Struck by / Hit by Object	13.25 ± 4.17	3.25 ± 0.46	15.0 ± 6.21
Transport-related (MVC + Non-motorized)	11.64 ± 4.77	3.66 ± 0.83	22.61 ± 13.5
Total	**12.62**	**3.72**	**18.67**

Table 3: Primary mechanism of injury vs. injury severity. The mean GCS score for all patients was 12.6. The mean AIS Head score for all patients was 3.7. The mean ISS score for all patients was 18.7. The most severe scores were recorded for patients for whom "self-harm" was the primary mechanism of injury (GCS=4.6, AIS Head=4.4, ISS=39.7). Abbreviations: MVC = Motor Vehicle Collision; GCS = Glasgow Coma Scale; AIS = Abbreviated Injury Scale; ISS = Injury Severity Score.

Significant between-group differences were noted for the primary mechanism of injury vs. hospital and ED length of stay (LOS). No significance was observed when comparing the mechanism of injury to ICU LOS. Trauma caused by the "other/miscellaneous" category resulted in the greatest average

hospital LOS (27.58 days) and ED LOS (18.53 hours). The greatest average ICU LOS was observed for the "struck by/hit by object" group (8.83 days). The shortest average hospital LOS was observed for the "assault" group (9.13 days), while the shortest ED and ICU LOS were recorded for the "self-harm" group (2.94 hours and 2.16 days, respectively). This may be accounted for by the fact that most patients whose primary mechanism of injury was self-harm died (68.18%; Table 5). Table 5 presents a comparison of mortality outcomes between primary mechanisms of injury groups. A chi-square test showed a significant association between mechanism and mortality (χ^2, $p<0.001$); most patients (N=987, 87.8%) survived overall, while self-harm had the highest mortality (68.2%). All patients who were categorized as having been struck by/hit by an object or as "other/miscellaneous" survived.

Table 4. Primary Mechanism of Injury and Length of Stay.

Primary Mechanism	Hospital Length of Stay (mean days ± SD)	ED Length of Stay (mean hours ± SD)	ICU Length of Stay (mean days ± SD)
Assault	9.13 ± 17.09	12.85 ± 11.35	3.37 ± 8.28
Falls	11.52 ± 18.65	13.74 ± 11.60	3.23 ± 5.81
Other / Miscellaneous	27.58 ± 74.98	18.53 ± 16.35	3.53 ± 4.83
Self-harm	10.18 ± 26.35	2.94 ± 4.84	2.16 ± 4.80
Struck by / Hit by Object	12.0 ± 22.64	12.21 ± 9.37	8.83 ± 23.26
Transport-related (MVC + Non-motorized)	12.44 ± 21.19	12.36 ± 18.74	4.95 ± 8.49

Table 4: Primary mechanism of injury compared to length of stay. The greatest average hospital length of stay was recorded for the "other/miscellaneous" group (27.6 days). The greatest average ED length of stay was recorded for the "other/miscellaneous" group (18.5 hours). The greatest average ICU length of stay was recorded for the "struck by/hit by an object" group (8.8 days). Significant between-group differences were observed when comparing the primary mechanism of injury to hospital and ED LOS. ICU LOS was not significant. Abbreviations: ED = Emergency Department; ICU = Intensive Care Unit; MVC = Motor Vehicle Collision.

Table 5. Primary Mechanism of Injury and Discharge Outcomes.

Primary Mechanism	Alive		Died		Total
	Count	%	Count	%	Count
Self-harm	7	31.82%	15	68.18%	22
Assault	129	92.14%	11	7.86%	140
Transport-related injuries (MVC + Non-motorized Transport combined)	233	84.42%	43	15.58%	276
Struck by / Hit by Object	8	100.00%	0	0.00%	8
Other / Miscellaneous	12	100.00%	0	0.00%	12

Falls	598	89.79%	68	10.21%	666
Total	**987**	**87.81%**	**137**	**12.19%**	**1124**

Table 5: Primary mechanism of injury compared to discharge outcomes. Most patients (N=987, 87.8%) survived their injuries. Most patients whose primary mechanism of injury was "self-harm" died (N=15, 68.2%). Abbreviations: MVC = Motor Vehicle Collision.

Significant between-group differences were observed for the primary mechanism of injury when compared to the number of days on mechanical ventilation (p<0.01; Table 6). Patients whose primary cause of TBI was self-harm had the fewest average number of days on the vent (1.5 days), while those who were in the "struck by/hit by" object category had the greatest number of vent days (2.9 days). Penetrating injuries had significantly higher ISS and lower GCS scores than blunt injuries, and a significantly greater number of vent days (Table 7).

Table 6. Primary Mechanism of Injury and Vent Days.

Primary Mechanism	Vent Days (mean ± SD)
Assault	1.49 ± 4.23
Falls	1.59 ± 6.61
Other / Miscellaneous	2.17 ± 3.43
Self-harm	1.45 ± 3.05
Struck by / Hit by Object	2.88 ± 8.13
Transport-related (MVC + Non-motorized)	2.16 ± 5.01

Table 6: Primary mechanism of injury compared to vent days. Kruskal–Wallis test indicated significant variation across mechanisms (p<0.01). "Self-harm" required the least average number of vent days (1.5 days), while "struck by/hit by object" required the greatest average number of vent days (2.9 days).

Table 7. Injury Type Compared to Injury Severity and Vent Days.

Variable	Blunt (mean ± SD)	Penetrating (mean ± SD)	p-value
AIS - Head	3.71 ± 0.82	4.00 ± 1.04	0.1925
ISS	18.50 ± 10.25	25.92 ± 12.30	4.16×10^{-5}
Initial GCS	12.72 ± 4.03	8.12 ± 5.76	5.86×10^{-5}
Vent Days	1.67 ± 5.88	4.32 ± 7.20	0.00253

Table 7: Injury type (blunt vs. penetrating) compared to injury severity (AIS Head, ISS, and initial GCS score on admission) and number of days on mechanical ventilation. Mann–Whitney U test indicated significant differences in ISS (p<0.001), GCS (p<0.001), and vent days (p<0.01) between groups. Abbreviations: AIS = Abbreviated Injury Scale; ISS = Injury Severity Score; GCS = Glasgow Coma Scale.

Discussion

The majority of our cohort suffered blunt trauma, most commonly due to falls, followed by transport-related injuries. A much smaller proportion of patients suffered penetrating injury, most commonly due to assault, followed by self-harm. Patients in the self-harm category were observed to have the most critical injury severity values and the fewest number of days on mechanical ventilation. Most patients in this category died. Trauma caused by the "other/miscellaneous" category resulted in the greatest average hospital and ED length of stays. Penetrating injuries resulted in significantly higher ISS and lower GCS scores than blunt injuries, as well as a significantly greater number of vent days.

The most common cause of non-fatal TBI globally is falls, followed closely by MVC. Falls are most likely to be attributed to hospitalization in patients 75 years and older, while individuals 15-34 years are most likely to be hospitalized for TBI caused by MVC [20]. This was the finding in our cohort, as well. Furthermore, the most common trauma type observed in our cohort was blunt injury (97.8%). Penetrating injuries are far less common but generally more severe. One population-based study that utilized data from the Trauma Quality Improvement Program (TQIP) of the National Trauma Data Bank (NTDB) reported that from 2017 to 2019, the rate of penetrating TBI remained relatively stable at approximately 6% [21].

In the Civilian population, the mortality rate for penetrating TBI is approximately 50% with self-inflicted injury and prehospital intubation being significant predictors of mortality [22]. The mortality rate for military personnel is lower, at 18%, potentially due to more rapid access to care [23]. Overall, we observed a mortality rate of 12.2%, which is lower than the 18-25% reported for moderate to severe TBI in existing literature [8,22,24]. This could in part be due to our data being collected at a level 1 trauma center. We also reported a lower percentage of penetrating injuries (2.2%), which typically result in higher mortality rates.

There is currently limited data comparing the primary mechanism of injury to outcomes such as hospital, ED, and ICU length of stay (LOS). However, several factors have been shown to influence LOS for patients with TBI. One recent retrospective review at a Level 1 Trauma center reported that prolonged hospital LOS (>28 days) was independently associated with Medicaid insurance, moderate to severe TBI, younger age, and the patients' need for post-acute care [25]. Similarly, another recent retrospective review at an urban trauma center found that patients with prolonged hospital LOS (>24 days) were more likely to have Medicaid insurance, moderate to severe TBI, and were less likely to be discharged home. Length of ICU stay and the need for mechanical ventilation were both independent predictors of hospital LOS [26]. In fact, while insurance payer was not examined in our study, lower socioeconomic status and Medicaid have been well established as predictors of LOS in TBI patients [27-29]. Future studies should consider including insurance payer as a modifier in predicting LOS. Our study found significant between-group differences when comparing the primary mechanism of injury to LOS, with the "other/miscellaneous" category resulting in the longest LOS. The "assault" and "self-harm" groups resulted in the shortest hospital LOS, and "self-harm" was associated with the greatest severity. The increased mortality rate in this group may explain the shorter LOS, but future research should focus on elucidating the specific forms of self-harm (e.g., gunshot wound, intentional jump/fall, etc.) and clinical outcomes. Most penetrating injuries in our cohort were due to assault or self-harm, but this was still a very small percentage of the total study population.

We also found significant variation across the primary mechanism of injury when compared to the number of days on mechanical ventilation, with the "self-harm" and "assault" groups requiring the least number of days. Patients suffering penetrating trauma were also significantly more likely to require an increased number of days on mechanical ventilation when compared to those with blunt trauma. Currently, there is no robust data relating the primary mechanism of injury to the number of days required on mechanical ventilation. The need for mechanical ventilation is largely determined by the severity of injury as well as patient consciousness and ability to protect their airway [30-32]. As with LOS, we can likely infer that the two groups requiring the least amount of time on mechanical

ventilation were due to the severity of sustained injuries and high rate of mortality seen in the "self-harm" group. Additionally, while this study did not consider the presence of polytrauma within our cohort, multiple injuries in TBI patients have been associated with increased vent days and increased hospital and ICU LOS [33].

Clinical Implications

Sociodemographic factors such as age, sex, race, and ethnicity are well-studied predictors of outcomes following severe TBI. However, the primary mechanism of injury has not been extensively studied as an independent predictor of outcomes such as hospital, ED, and ICU length of stay, and number of days required on mechanical ventilation. We aimed to address this gap in the literature. Most notably, we found that self-inflicted injuries required the least average number of vent days and the shortest average ED and ICU length of stay. Self-inflicted injuries also resulted in the greatest mortality, thus highlighting the potentially devastating effects of TBI caused by self-harm, and the need to continue investigating these relationships.

Strengths and Limitations

One strength of our study is the large sample size of our cohort, providing substantial statistical power. We explored a relationship that is not well documented in existing literature, with the hopes of better understanding outcomes associated with individual mechanisms of injury and optimizing care based on the type of injury. Limitations include decreased generalizability, information bias, and the presence of missing or incomplete data, due to this being a retrospective review. We also did not collect data on well-known modifiers of TBI outcomes, such as insurance payer status and presence of polytrauma.

Future Perspectives

Future studies should include variables known to impact TBI outcomes, such as insurance payer status and presence of polytrauma, in the analysis. Additionally, a further breakdown of specific causes and types of injury could better explain discrepancies in our findings, such as short LOS within the "self-harm" group and increased length of stay in the "other/miscellaneous" group.

Conclusion

In conclusion, we address an important gap in current research. While most of our findings agree with existing literature, they differ in that the group with the worst injury severity ratings (self-harm) resulted in the shortest ED and ICU length of stay, and the second shortest hospital length of stay after the "assault" group. This paradox is likely explained by the high early mortality in the self-harm group, which limited opportunities for prolonged inpatient care. Additionally, the "other/miscellaneous" category demonstrated disproportionately prolonged hospital and ED stays, underscoring the need to better understand complex or atypical trauma presentations. These findings confirm that the primary mechanism of injury plays a critical role not only in injury severity but also in downstream outcomes and should be considered in prognostic modeling and acute care planning for TBI patients. This study has taken an important step toward predicting outcomes based on the primary mechanism of TBI and can pave the way for future research investigating these associations.

Institutional Review Board Statement: This retrospective study was approved by the IRB at Elmhurst Facility on 5 July 2024, with IRB number 24-12-092-05G.

Informed Consent Statement: Retrospective analysis was performed on anonymized data, and informed consent was not applicable.

Data Availability Statement: The data were requested from the Elmhurst Trauma registry and extracted using electronic medical records after receiving approval from the Institutional Review Board at our facility (Elmhurst Hospital Center).

Conflicts of Interest: The authors have no competing interests to declare.

References

1. National Institute of Neurological Disorders and Stroke. Traumatic Brain Injury (TBI). www.ninds.nih.gov. Published July 21, 2025. https://www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi

2. Brasure M, Lamberty GJ, Sayer NA, et al. Multidisciplinary Postacute Rehabilitation for Moderate to Severe Traumatic Brain Injury in Adults [Internet]. Rockville (MD): Agency for Healthcare Research and Quality (US); 2012 Jun. (Comparative Effectiveness Reviews, No. 72.) Table 1, Criteria used to classify TBI severity. Available from: https://www.ncbi.nlm.nih.gov/books/NBK98986/table/introduction.t1/

3. CDC. TBI Data. Traumatic Brain Injury & Concussion. Published October 29, 2024. https://www.cdc.gov/traumatic-brain-injury/data-research/index.html

4. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Board on Health Care Services; Board on Health Sciences Policy; Committee on Accelerating Progress in Traumatic Brain Injury Research and Care; Matney C, Bowman K, Berwick D, editors. Traumatic Brain Injury: A Roadmap for Accelerating Progress. Washington (DC): National Academies Press (US); 2022 Feb 1. 2, The Scope and Burden of Traumatic Brain Injury. Available from: https://www.ncbi.nlm.nih.gov/books/NBK580076/

5. Haarbauer-Krupa J, Pugh MJ, Prager EM, Harmon N, Wolfe J, Yaffe K. Epidemiology of Chronic Effects of Traumatic Brain Injury. *J Neurotrauma*. 2021;38(23):3235-3247. doi:10.1089/neu.2021.0062

6. Gupte R, Brooks W, Vukas R, Pierce J, Harris J. Sex Differences in Traumatic Brain Injury: What We Know and What We Should Know. *J Neurotrauma*. 2019;36(22):3063-3091. doi:10.1089/neu.2018.6171

7. Späni CB, Braun DJ, Van Eldik LJ. Sex-related responses after traumatic brain injury: Considerations for preclinical modeling. *Front Neuroendocrinol*. 2018;50:52-66. doi:10.1016/j.yfrne.2018.03.006

8. Dawood MH, Fazli Y, Lund S, et al. Mortality trends of traumatic brain injuries in the adult population of the United States: a CDC WONDER analysis from 1999 to 2020. *BMC Public Health*. 2025;25(1):482. Published 2025 Feb 5. doi:10.1186/s12889-025-21657-z

9. Maldonado J, Huang JH, Childs EW, Tharakan B. Racial/Ethnic Differences in Traumatic Brain Injury: Pathophysiology, Outcomes, and Future Directions. *J Neurotrauma*. 2023;40(5-6):502-513. doi:10.1089/neu.2021.0455

10. Lai H, Ahmad H, Mubashir T, et al. Racial and Socioeconomic Disparities in Traumatic Brain Injury Outcomes: Insights From a Nationwide Analysis. *Neurosurgery*. 2024;97(1):204-212. Published 2024 Nov 18. doi:10.1227/neu.0000000000003276

11. Zhong H, Feng Y, Shen J, et al. Global Burden of Traumatic Brain Injury in 204 Countries and Territories From 1990 to 2021. *Am J Prev Med*. 2025;68(4):754-763. doi:10.1016/j.amepre.2025.01.001

12. Yan J, Wang C, Sun B. Global, regional, and national burdens of traumatic brain injury from 1990 to 2021. *Front Public Health*. 2025;13:1556147. Published 2025 Apr 14. doi:10.3389/fpubh.2025.1556147

13. Peterson A, Thomas K, Kegler S. Disparities in traumatic brain injury-related the United States, 2021. *Brain Inj*. 2025;39(3):187-198. doi:10.1080/02699052.2024.2415933

14. Daugherty J, Waltzman D, Sarmiento K, Xu L. Traumatic Brain Injury-Related Deaths by Race/Ethnicity, Sex, Intent, and Mechanism of Injury - United States, 2000-2017. *MMWR Morb Mortal Wkly Rep*. 2019;68(46):1050-1056. Published 2019 Nov 22. doi:10.15585/mmwr.mm6846a2

15. Jochems D, van Rein E, Niemeijer M, et al. Incidence, causes, and consequences of moderate and severe traumatic brain injury as determined by Abbreviated Injury Score in the Netherlands. *Sci Rep*. 2021;11(1):19985. Published 2021 Oct 7. doi:10.1038/s41598-021-99484-6

16. Wroblewski TH, Ononogbu-Uche F, Jagtiani P, Roberts MC, Bigdeli TB, Barthélemy EJ. Structural Inequities in Brain Trauma Outcome Prevalences Reported in the All of Us Database. *Am J Epidemiol*. Published online February 17, 2025. doi:10.1093/aje/kwaf030

17. Miller GF, Daugherty J, Waltzman D, Sarmiento K. Predictors of traumatic brain injury morbidity and mortality: Examination of data from the national trauma data bank: Predictors of TBI morbidity & mortality. *Injury*. 2021;52(5):1138-1144. doi:10.1016/j.injury.2021.01.042

18. Gu L, Zhang L, Li C, et al. Global, Regional, and National Burden of Traumatic Brain Injury, 1990-2021: A Systematic Analysis for the Global Burden of Disease Study 2021. *J Neurotrauma*. Published online July 7, 2025. doi:10.1089/neu.2025.0039

19. Dams-O'Connor K, Juengst SB, Bogner J, et al. Traumatic brain injury as a chronic disease: insights from the United States Traumatic Brain Injury Model Systems Research Program. *Lancet Neurol*. 2023;22(6):517-528. doi:10.1016/S1474-4422(23)00065-0

20. Peterson AB, Thomas KE. Incidence of Nonfatal Traumatic Brain Injury-Related Hospitalizations - United States, 2018. *MMWR Morb Mortal Wkly Rep*. 2021;70(48):1664-1668. Published 2021 Dec 3. doi:10.15585/mmwr.mm7048a3

21. Mansour A, Powla PP, Alvarado-Dyer R, et al. Comparative Analysis of Clinical Severity and Outcomes in Penetrating Versus Blunt Traumatic Brain Injury Propensity Matched Cohorts. *Neurotrauma Rep*. 2024;5(1):348-358. Published 2024 Apr 3. doi:10.1089/neur.2024.0009

22. Skarupa DJ, Khan M, Hsu A, et al. Trends in civilian penetrating brain injury: A review of 26,871 patients. *Am J Surg*. 2019;218(2):255-260. doi:10.1016/j.amjsurg.2018.11.034

23. Karras CL, Texakalidis P, Nie JZ, et al. Outcomes Following Penetrating Brain Injuries in Military Settings: A Systematic Review and Meta-Analysis. *World Neurosurg*. 2022;166:39-48. doi:10.1016/j.wneu.2022.07.062

24. Graves WC, Oyesanya TO, Gormley M, et al. Pre- and in-hospital mortality for moderate-to-severe traumatic brain injuries: an analysis of the National Trauma Data Bank (2008-2014). *Brain Inj*. 2021;35(3):265-274. doi:10.1080/02699052.2021.1873419

25. Yue JK, Krishnan N, Chyall L, et al. Socioeconomic and clinical factors associated with prolonged hospital length of stay after traumatic brain injury. *Injury*. 2023;54(9):110815. doi:10.1016/j.injury.2023.05.046

26. Taylor SV, Loo GT, Richardson LD, Legome E. Patient Factors Associated With Prolonged Length of Stay After Traumatic Brain Injury. *Cureus*. 2024;16(5):e59989. Published 2024 May 9. doi:10.7759/cureus 59989

27. Yue JK, Krishnan N, Toretsky C, et al. The insurance payer is associated with the length of stay after traumatic brain injury. *Am J Manag Care*. 2025;31(4):173-181. doi:10.37765/ajmc.2025.89688

28. Yue JK, Krishnan N, Chyall L, et al. Predictors of Extreme Hospital Length of Stay After Traumatic Brain Injury. *World Neurosurg*. 2022;167:e998-e1005. doi:10.1016/j.wneu.2022.08.122

29. Wadhwa A, Purohit S, Ramirez-Velandia F, Enriquez-Marulanda A, Ogilvy CS. Socioeconomic Disparities in the Clinical Outcomes of Pediatric Traumatic Brain Injury: A Nationwide Analysis of the Past Decade. *World Neurosurg*. 2025;194:123420. doi:10.1016/j.wneu.2024.11.003

30. Becker ER, Wetmore GC, Goodman MD, Rodriguez D Jr, Branson RD. Review of Ventilation in Traumatic Brain Injury. *Respir Care*. 2025;70(4):450-457. doi:10.1089/respcare.12796

31. Taran S, Cho SM, Stevens RD. Mechanical Ventilation in Patients with Traumatic Brain Injury: Is it so Different?. *Neurocrit Care*. 2023;38(1):178-191. doi:10.1007/s12028-022-01593-1

32.

33. Meyfroidt G, Bouzat P, Casaer MP, et al. Management of moderate to severe traumatic brain injury: an update for the intensivist. *Intensive Care Med*. 2022;48(6):649-666. doi:10.1007/s00134-022-06702-4

34. Niemeyer M, Jochems D, Houwert RM, van Es MA, Leenen L, van Wessem K. Mortality in polytrauma patients with moderate to severe TBI on par with isolated TBI patients: TBI as last frontier in polytrauma patients. *Injury*. 2022;53(4):1443-1448. doi:10.1016/j.injury.2022.01.009