

General

Motor Vehicle Collision Associated TBI: Predictors of Injury severity

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Objective

To determine the predictors of traumatic head injury (TBI) severity in adult patients involved in motor vehicle collisions or accidents, and to report on the outcomes of hospital admission, in-hospital death, and return to the ED within 72 hours of discharge.

Methods

This is an observational cohort of adult patients (≥ 18 years) who sustained a TBI through involvement in motor vehicle collisions (MVC). Demographic, pre-hospital and clinical data were collected from medical records of patients.

Results

In our cohort, patients who had loss of consciousness, alteration of consciousness, or post-traumatic amnesia were individual predictors of more severe traumatic brain injury. TBI severity was categorized by using GCS scores on emergency department arrival. Similarly, male patients, those who did not wear seat belts, and those with alcohol consumption were more likely to have severe TBI. When controlling for sex, loss of consciousness, no seat belt use, and alcohol consumption prior to injury were still statistically significant predictors of having more serious traumatic brain injury.

Conclusion

Lack of seat belt use, alcohol consumption before injury, and loss of consciousness because of injury are significant predictors of having more severe head injury. These data support a call for action to implement more widespread injury prevention, seat belt use education and advocacy.

INTRODUCTION

Motor vehicle collisions (MVCs) are a leading cause of injury and death worldwide, posing a significant public health challenge. Globally, road traffic accidents are a major contributor to the burden of traumatic brain injuries (TBIs), which are often seen as either isolated injuries or a diagnosis involved in multi-trauma scenarios. The epidemiology of MVCs highlights a concerning prevalence of TBIs, particularly affecting individuals during their prime working ages.

In the United States, road traffic accidents rank among the top causes of injury-related mortality and morbidity. According to the National Highway Traffic Safety Administration (NHTSA), there were approximately 38,680 fatalities in MVCs in 2020, with an additional 2.7 million injuries in 2021 from road traffic incidents in the United States.¹ Among these injuries, TBIs due to MVCs account for 50% of fatal and non-fatal TBIs.² The Centers for Disease Control and Prevention (CDC) reports that TBIs, including those resulting from MVCs, lead to over 280,000 hospitalizations

and nearly 60,000 deaths annually in the U.S.³ Additionally, year-over-year MVCs increase as a leading cause of injury and death in the United States, underscoring the exponential role MVCs continue to play as a contributor to TBIs and ultimately their contribution to a public health crisis in the U.S. [4].

Globally, the World Health Organization (WHO) estimates that over 1.35 million people die each year due to road traffic accidents, with an additional 20 to 50 million sustaining non-fatal, however, serious injuries.⁴ TBIs are a predominant form of injury frequently occurring in these accidents, significantly contributing to the overall global burden of neurological impairment and disability.²

The impact of TBI is far-reaching, especially when considering the demographics of those affected. TBIs predominantly occur as a trimodal age-specific TBI incidence, including the age groups of children, young adults, and the elderly. In young adults, the leading cause of TBIs is MVCs, while children and elderly adults acquire TBIs from falls as the number one cause, although MVCs are the second leading cause.³ Men in the adolescence/young adult cate-

gories have a higher incidence of TBI and are more likely to be hospitalized.⁴ Working-age TBI incidence and prevalence significantly impact economic productivity as it bears the greatest burden when a working-age individual who has suffered a TBI is incapacitated and unable to work. Studies indicate that TBIs can lead to long-term disabilities, affecting cognitive function, emotional stability, and poorer quality of life.⁵

Additionally, the consumption of alcohol has been identified as a significant risk factor for MVCs leading to TBIs.⁶ Alcohol intoxication was associated with increased mortality in moderate to severe TBI cases, indicating a direct correlation between alcohol use and worse clinical outcomes.⁷ Furthermore, alcohol has been shown to influence injury patterns, although its direct effect on short-term mortality remains debated.⁸ These findings suggest that alcohol's impact on MVC-related injuries and TBIs necessitates continued research to explore its effects on peri-injury symptoms, injury severity, and long-term prognosis.

The intersection of alcohol use, MVCs, and TBIs highlights the urgent need for targeted MVC prevention strategies, evaluation of severity of TBI and effective management protocols, as these injuries contribute a significant impact on measurable productivity of working age individuals both short term and long term. Addressing the causes and consequences of TBIs resulting from MVCs is crucial for both public health and economic stability, especially those that are preventable. By reducing the incidence of these injuries, mitigating long-term disability, and enhancing the quality of life for affected individuals, significant improvements in overall health outcomes can be achieved.

MATERIALS AND METHODS

This was an observational cohort study that included adult patients (18 years or higher) presenting to the emergency department (ED) following an MVC during a 30-month time frame. The study was conducted at a level one trauma center that is home to both emergency medicine and general surgery residency programs. Collected variables included demographic such as age, gender, race; pre-hospital, such as GCS score by EMS, glucose levels by EMS; injury related, such as loss of consciousness (LOC), seizure, vomiting, alteration of consciousness (AOC), post-traumatic amnesia (PTA), seat belt use, location of patient at the time of MVC (driver, passenger, other), use of alcohol by patient before MVC, CGS score on ED arrival etc. Severity of TBI was classified according to the Glasgow coma scale, with mild defined as 13-15, moderate being 9-12, and severe being anything less than nine. Data regarding brain CT scans and their results were also retrieved. Statistical analysis was performed with use of JMP 16.0 Pro for Mac. For analytical purposes, whenever applicable, the patients with unknown status for any variable were treated as not having that factor. Chi-square tests of independence were used to analyze the association between TBI severity and individual independent variables. Logistic regression modeling was used to determine the effects of predictors on TBI severity, and coefficients of variance reported.⁹ As there were few pa-

tients in moderate TBI severity group, and the outcomes for those were more in line with severe group than mild TBI, we grouped the moderate and severe TBI together for regression analysis. For all analytical tests, level of significance was set up as $p\text{-value} < 0.05$. Our institution's research committee deemed the study minimal risk and thus exempt.

RESULTS

The characteristics of the cohort of 816 is summarized in [table 1](#). The median age was 31 (IQR: 23-49, R: 18-90). 529 (65%) arrived via ambulance. The breakdown of severity in the pre-hospital setting was 74% mild, 5.5% moderate, and 20.5% severe. In the ED ($n=816$), the breakdown was 81% mild (GCS 13-15), 3% moderate (GCS 9-12), and 16% severe (GCS 3-8) [[figure 1](#)].

Males were more likely to sustain moderate or severe TBI as defined by GCS score (88.9%, 1.5%, 9.2% vs. 75.7%, 3.2%, 21.1% for mild, moderate and severe categories respectively; $p < 0.0001$). Patients who had a positive LOC, AOC, or PTA were more likely to sustain a moderate or severe TBI. Having a seizure was also significantly associated with increased TBI severity ($P=0.001$). Although vomiting was associated with greater TBI severity, the results were not statistically significant ([table 2](#)).

Patients who did not wear seatbelts had more severe TBI compared to those who had seat belt on at the time of MVC ([table 3](#)). Also, patients with alcohol consumption before their involvement in accidents were more likely to have severe TBI compared to those without alcohol consumption ([table 2](#)). Logistic regression analysis revealed that loss of consciousness ($p < 0.0001$, OR=14.5 CI=2.98-261.8), no seat belt ($p=0.0069$, OR=2.77 CI=1.31-6.1), and alcohol consumption before injury ($p=0.0315$, OR=2.2 CI=1.07-4.59), were predictive of more severe TBI, when controlling for the sex of the patient. In other words, each of these factors increased the odds of worse TBI severity by at least twofold.

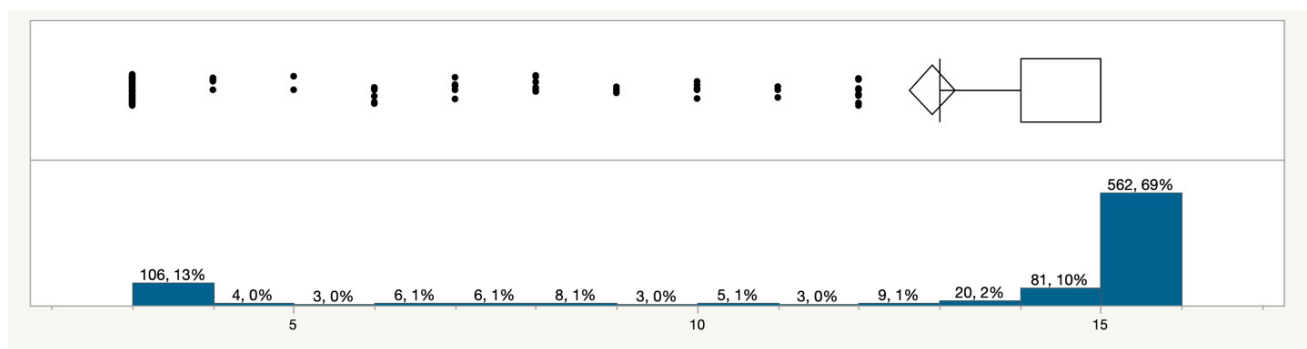
DISCUSSION

While this study's findings, including alcohol consumption correlation, seatbelt use and peri-injury symptomatology, contribute to the growing body of research on risk factors for TBI severity and impact on patient outcome, integrating them with refined prognostic models such as the IMPACT (International Mission for Prognosis and Clinical Trials in TBI) and the CRASH (Corticosteroid Randomization After Significant Head Injury) models, which include CT scan findings, age, and laboratory results, could further enhance clinical assessment to improve patient outcomes and TBI severity.¹⁰

In the current study, peri-injury symptomatology was found to be significantly associated with increased TBI severity as measured by the Glasgow Coma Scale. Accordingly, seizures, LOC, AOC, and PTA should be considered early predictors of worse severity in patients who sustain a head injury during their motor vehicle collision. An emergency department based prospective study of 412 mild TBI

Table 1. summary of cohort characteristics.

Variable	Frequency
Sex	58% male
Race	75% White; 17% Black; 5% Hispanic, 3% other
Associated vomiting	4%
Associated seizure	1%
Loss of consciousness	28% no LOC; 60% +LOC; 12% unknown
Alteration in consciousness	53% no AOC; 34% +AOC; 13% unknown
Post-traumatic amnesia	49% no PTA; 30% +PTA; 21% unknown
Location of patient in the car	62% driver's seat; 13% front seat passenger; 5% back seat passenger
Wearing seatbelt	30% no seatbelt; 46% wore seatbelt; 24% unknown
Consumed alcohol before the accident	49% no alcohol; 22% did consume alcohol; 30% unknown

**Figure 1. Histogram depicting the distribution of Emergency Department GCS scores.****Table 2. Association of peri-injury symptoms to severity of TBI**

		Mild	Moderate	Severe	P-value
Loss of consciousness	Yes (n=490)	357 (72.9%)	13 (2.6%)	120 (24.5%)	<0.0001
	No or unknown (n=227)	220 (96.9%)	3 (1.3%)	4 (1.8%)	
Alteration of consciousness	Yes (n=279)	170 (60.9%)	17 (6.1%)	92 (33%)	<0.0001
	No or unknown (n=431)	427 (99%)	1 (0.3%)	3 (0.7%)	
Post-traumatic Amnesia	Yes (n=243)	223 (91.8%)	4 (1.6%)	16 (6.6%)	0.002
	No or unknown (n=401)	391 (97.5%)	4 (1%)	6 (1.5%)	
Vomiting	Yes (n=31)	26 (83.9%)	0	5 (16.1%)	0.67
	No or unknown (n=769)	635 (82.5%)	19 (2.5%)	115 (15%)	
Seizures	Yes (n=6)	2 (33.3%)	0	4 (66.7%)	0.001
	No (n=794) or unknown	660 (83.1%)	19 (2.4%)	115 (14.5%)	

patients found that these symptoms were also associated with a higher risk of developing post-concussive syndrome, characterized by headache, insomnia, memory problems, and fatigue.¹¹ A retrospective study of 2787 mild TBI patients found that the mechanism of motor vehicle collision was an independent risk factor for patients to return to the emergency department within 72 hours of injury.¹²

The correlation between post-traumatic seizures and TBI severity is supported by a Nigerian study of 266 patients, which found that TBI severity was a risk factor for post-

traumatic seizures.¹³ PTA is classically defined as the period from injury until the resumption of the ability to store new memories early after a TBI.¹⁴ PTA has been reported as a predictor of severity by other research; one study found that greater duration of amnesia is associated with greater TBI severity, as measured by clinical outcomes at one year post-injury.¹⁵

The data from the current study also indicate that seat-belt use is a predictor of significantly less severity in patients who sustain a head injury during an MVC. With an

Table 3. Impact of seat belt use and alcohol consumption before injury on severity of TBI

Emergency department TBI severity (based on ED arrival GCS score)				p-value
Seat Belt	Mild	Moderate	Severe	<0.0001
Without seat belt or unknown (n=244)	177 (72.54%)	8 (3.28%)	59 (24.18%)	
With seat belt (n=374)	345 (92.25%)	5 (1.34%)	24 (6.42%)	
Alcohol Before Injury				<0.0001
Alcohol consumption (n=176)	130 (73.86%)	6 (3.41%)	40 (22.73%)	
No alcohol consumption or unknown (n=395)	357 (90.38%)	8 (2.03%)	30 (7.59%)	

odds ratio of 2.77, lack of seatbelt use is associated with almost 3 times higher odds of worse TBI severity.¹⁶ A related 2021 analysis of over 800 patients reports that lack of seat-belt use was not only associated with worse TBI severity, but also with having an abnormal brain CT, being admitted to the hospital, having an ICU stay, and death during the hospital admission.¹⁷

The results of this study assert the association between alcohol use and an increased TBI severity post MVCs. Patients in our cohort who had consumed alcohol just prior to their injuries were significantly more likely to sustain a severe TBI than those who did not consume alcohol. These findings align with previous studies which demonstrated increased severity of TBIs amongst alcohol positive patients.¹⁸ These results highlight a continued effort to implement targeted public-health interventions aimed at reducing alcohol-related MVCs to mitigate the risk of developing more severe TBIs.

There are important limitations to the current study. The determinants of severity identified in this study are not comprehensive; other studies have recognized additional indicators that may be helpful in the proper diagnosis and prognosis of TBIs as mentioned as IMPACT and CRASH. Additionally, other studies including an emergency department study of 123 MVC patients with TBI and 100 trauma controls reports that pre-injury physical and psychiatric problems, particularly anxiety, are predictors of post-injury symptoms at 3 months.¹⁹

CONCLUSIONS

Lack of seat belt use, alcohol consumption before injury, and loss of consciousness because of injury are significant predictors of having more severe head injury. These data support a call for action to implement more widespread injury prevention, seat belt use education and advocacy.

AUTHOR CONTRIBUTIONS

EN and LG drafted the initial manuscript. HS and NK edited and critically revised the manuscript. LG supervised the project. All authors read and approved the final manuscript.

FUNDING

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INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki. The Orlando College of Osteopathic Medicine's Research Committee determined this study to be exempt.(study #2024-01).

INFORMED CONSENT STATEMENT

A waiver of informed consent was granted for this retrospective chart review study as it poses minimal risk to patients, involves only de-identified medical data, and obtaining consent from past patients would be impractical due to the significant challenges in contacting them.

DATA AVAILABILITY STATEMENT

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author(s).

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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