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Unhelmeted Motorcycle Riders Have Increased Injury Burden: A Need to Revisit Universal Helmet Laws

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ABSTRACT

Background: The aim of this study was to compare hospital outcomes for patients in a motorcycle collision with and without helmet use. The study was conducted as a retrospective analysis of the National Trauma Data Bank's 2013 data set, which included reported data from 100 hospitals across the United States.

Methods: Inclusion criterion for this study is a motorcycle crash involving a driver or passenger. The total number of patients in motorcycle crashes as reported by the National Trauma Data Bank in 2013 was 10,345. Helmet use, hospital stay, ICU and ventilation days, mortality, Glasgow Coma Score, Injury Severity Score, patient payer mix, and complication data were obtained.

Results: Patients were divided into two groups: those wearing a helmet ($n = 6250$) and those without ($n = 4095$). Patients not wearing a helmet had an increased risk of admission to the ICU (OR = 1.36, $P < 0.001$, CI 1.25-1.48), requiring ventilation support (OR = 1.55, $P < 0.001$, CI 1.39-1.72), presenting with a Glasgow Coma Score of eight or below (OR = 2.15, $P < 0.001$), and in-patient mortality (OR = 2.00, $P < 0.001$, CI 1.58-2.54). Unhelmeted patients were more likely to have government insurance or be uninsured than those patients wearing a helmet ($P < 0.001$).

Conclusions: It is not well understood why many states are repealing or have repealed universal helmet laws. Lack of helmet use increases the severity of injury in traumatized patients leading to a substantial financial impact on health care costs. Our analysis suggests the need to revisit the issue regarding laws that require protective headwear while riding motorcycles because of the individual and societal impact.

Level of Evidence: III.

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Introduction

The United States Bureau of Transportation estimates that there are currently over 800,000 motorcyclists in the United States. Motorcycle use exposes the rider to a vast array of risks. Helmet laws, first introduced in 1967, were designed to protect the rider from severe traumatic brain injuries and increase survivorship. The helmet laws were federally regulated, requiring all motorcycle riders, regardless of age, to wear helmets. However, concerted efforts by motorcycle advocacy groups lobbied Congress to modify the law and allow individual states to decide on helmet use and age requirements.[1,2] For instance, A Brotherhood Against Totality Enactment (ABATE) was one of the organizations to influence Congress in 1975 to repeal helmet laws citing freedom of motorcyclists and concern of injury caused by helmet use.[2] Since the repeals, individual states and hospitals have attempted to study the impact of these changes on patient outcome and health care costs.

Several governmental and lay press publications have recognized the resultant changes at the state level. The Insurance Institute for Highway Safety indicates that only 19 states and the District of Columbia currently have laws requiring a rider to wear a helmet (Table 1). Helmet laws can have drastic implications, as the helmet remains the sole head impact barrier available to the rider or passenger. In 2013, a total of 32,719 people were killed in traffic-related accidents and 2,313,000 were injured.[3] Specific to motorcycle crashes (MCCs), 4668 mortalities were reported in 2013, with 88,000 injuries.[3] Motorcycle riders continue to be the most vulnerable group of crash victims among all vehicular trauma.

The intent of the present study is to analyze and assess the medical outcomes related to the use of helmets in MCCs. Our hypothesis is that unhelmeted motorcycle riders involved in an accident will have a greater risk of mortality, high injury severity, including neurologic injury, and increased health care utilization (ICU admission and length of stay).

Methods

The National Trauma Data Bank (NTDB), maintained by the American College of Surgeons (ACS) Committee on Trauma, was queried and analyzed retrospectively. The most recent version available at the conduction of this study was the 2013 data set. A total of 94 hospitals submitted data to the NTDB for the data set we used. The ACS trauma level designation was as follows: 38 (40.4%) level 1, 29 (30.9%) level 2, and 27 (28.7%) did not have ACS designation. The study involved retrospective review of a national database without direct or indirect intervention contact of patients. Study was approved by Emory University School of Medicine Department of Orthopedics.

Inclusion criteria for this study included an MCC involving a driver or passenger. Any crash which did not involve a motorcycle vehicle was excluded from the study. The total number of individuals involved in MCCs as reported by the NTDB in 2013 was 10,345. Additional data obtained included helmet use, number of hospital and ICU days, number of mechanical ventilation delays, mortality (on-arrival or inpatient), Glasgow Coma Score (GCS), Injury Severity Score (ISS), insurance status, and development of at least one complication. A score of 15 on the GCS is considered normal, whereas a score of three is the lowest possible score indicating no verbal, motor, or eye movement response.[3] GCS was considered to be clinically low and severe in nature if it was reported to be eight or less. An ISS score of 25 or greater was used to define significant injury to account for at least one critical injury or multiple minor to severe injuries.

Table 1 – Status of helmet laws among states in the United States according to the Insurance Institute for Highway Safety (updated October 2016).

States with universal helmet laws		States with partial helmet laws	
Alabama	Nebraska	Alaska	Michigan
California	Nevada	Arizona	Minnesota
District of Columbia	New Jersey	Arkansas	Montana
Georgia	North Carolina	Colorado	New Mexico
Louisiana	Oregon	Connecticut	Ohio
Maryland	Tennessee	North Dakota	Delaware
Massachusetts	Vermont	Florida	Oklahoma
Mississippi	Virginia	Hawaii	Pennsylvania
West Virginia	New York	Idaho	Rhode Island
Missouri		Indiana	South Carolina
		South Dakota	Kansas
		Texas	Kentucky
		Wisconsin	Maine
		Wyoming	Utah
States with no helmet laws			
Illinois			
Iowa			
New Hampshire			

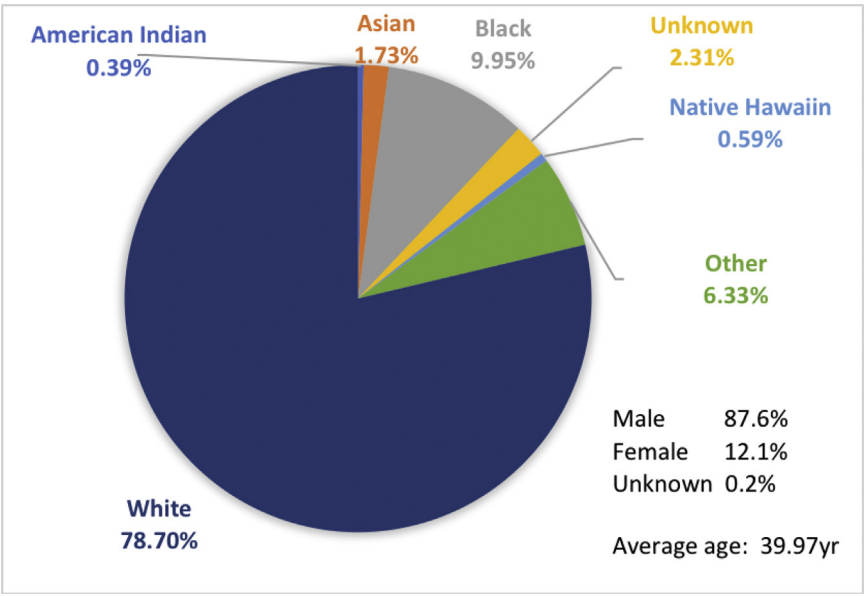

Fig – Demographics of study population (n = 10,345). (Color version of figure is available online.)

Data points were filtered and matched to the MCC data using a unique key which was assigned to each patient by the NTDB. This filtered data were then cross-checked for accuracy with the raw NTDB data using random selection and verification of various patient keys. Categorical variables were then analyzed using a chi-square test, and continuous variables were analyzed using independent and nonparametric t-tests, with significance at a P-value of <0.05. Multivariate analysis was then performed using logistic regression to identify independent variables associated with mortality, ICU admission, and need for mechanical ventilation.

Table 2 – Univariate analysis of Helmeted *versus* Unhelmeted patients presenting after trauma.

Independent t-test analysis	Helmeted	Unhelmeted	P-value
LOS (d)	6.46 (8.79)	6.80 (9.69)	0.81
ICU (d)	6.40 (8.25)	6.79 (8.22)	0.77
Ventilation support (d)	7.37 (8.64)	7.18 (7.91)	0.59
GCS	14.08 (2.91)	13.24 (3.87)	<0.001
Chi-square analysis			
ICU admission	1902 (31.20%)	1525 (38.10%)	<0.001
Ventilation support	810 (13.50%)	755 (19.50%)	<0.001
GCS <8 on admission	421 (6.80%)	544 (13.60%)	<0.001
In-patient death	126 (2.00%)	162 (4.0%)	<0.001
ISS >25 on admission	605 (10.5%)	564 (14.10%)	<0.001
Insurance status			
Private	3402 (60.90%)	2107 (56.0%)	
Medicare/Medicaid	923 (16.50%)	697 (18.5%)	
Uninsured	1040 (18.60%)	806 (21.40%)	<0.001

Results

In 2013, the NTDB reported data variables on 611,376 patients, which included data from 10,345 involved in MCCs (1.69%). Of these, 6250 (60.4%) were helmeted and 4095 (39.6%) were unhelmeted. The average age was found to be 39.97 yrs (15.9 SD), and general demographic information is illustrated in Figure. On arrival to the trauma bay, unhelmeted patients had a lower mean GCS (13 ± 3.9) compared with those who were helmeted (14 ± 2.9) (P < 0.001). The unhelmeted population also had a higher ISS (13 ± 10.8) compared to those who were helmeted (12 ± 9.9) (P < 0.001). 61 (1.5%) unhelmeted patients arrived with no signs of life compared with 75 (1.2%) patients who were helmeted (P = 0.22). Patients who were not wearing a helmet were more likely to have government insurance or be uninsured and less likely to have private insurance than those patients wearing helmets (P < 0.001). No significant difference was seen between the two groups regarding the development of at least one complication (P = 0.36) (Table 2).

Regression analysis revealed unhelmeted patients have a higher chance of ICU admission (OR = 1.36, 95% CI 1.25-1.48, P < 0.001), need for ventilatory support (OR = 1.55, 95% CI 1.39-1.72, P < 0.001), a GCS of eight or lower (OR = 2.15, 95% CI 1.89-2.46, P < 0.001), an ISS of 25 or above (OR = 1.4, CI 1.24-1.58, P < 0.001), and in-patient mortality (OR = 2.0, CI 1.581-2.54, P < 0.001) (Table 3).

Although those who were unhelmeted had a greater chance of admission to the ICU and requiring ventilatory support, no significant difference was noted regarding time spent in the ICU, in the hospital, or on ventilation between groups. Mean time requiring ventilatory support was 7.2 ± 7.9 d for those unhelmeted compared with 7.4 ± 8.6 d for those helmeted (P = 0.59). The average ICU length of stay was 6.8 ± 8.2 d for unhelmeted patients *versus* 6.4 ± 8.2 d for helmeted patients (P = 0.77). Mean hospital length of stay was 6.8 ± 9.7 d for those unhelmeted compared to 6.5 ± 8.8 d for those

Table 3 – Multivariate Analysis of helmeted and unhelmeted patients.

Binary logistic regression	OR	95% CI	P Value
Univariate analysis			
ICU admission	1.36	1.25-1.48	<0.001
Days on ventilation support	1.55	1.39-1.72	<0.001
GCS <8	2.15	1.89-2.46	<0.001
In-patient death	2.00	1.58-2.54	<0.001
Multivariate analysis			
ICU admission	1.23	1.10-1.36	<0.001
Days on ventilation support	0.97	0.82-1.13	0.688
GCS<8	1.93	1.63-2.29	<0.001
In-patient death	1.23	0.95-1.61	0.118

helmeted ($P = 0.07$). The in-patient mortality was increased for unhelmeted patients at 4% *versus* 2% for helmeted patients ($P < 0.001$).

Multivariate logistic analysis was performed to identify independent factors associated with not wearing a helmet. All variables with a significance of $P < 0.05$ on univariate analysis were input into our model, which was predictive of unhelmeted patients in 62.4% of cases (Nagelkerke $R^2 = 0.021$). Inclusion of other factors did not substantially change the results of the multivariate analysis. Low GCS on arrival (OR = 1.9, $P < 0.001$) and admission to the ICU (OR = 1.2, $P < 0.001$) were independent predictors of unhelmeted patients (Table 3).

Discussion

The results of this study indicate the unfavorable nature of the outcomes for unhelmeted riders involved in MCCs. Unhelmeted riders had higher ISS scores, lower GCS scores, higher rates of ICU admission, need for mechanical ventilation, and in-hospital mortality when compared with helmeted riders. Costs of overall hospital care for unhelmeted patients can be inferred to be higher, given the increased level of care required and worse presenting condition of unhelmeted patients compared with helmeted patients on arrival. Furthermore, given that unhelmeted riders were more likely to have governmental insurance or no insurance, the burden of the increased costs in this patient population falls on an already overburdened health care system.

Strengths and weaknesses of study

The availability of a diverse amount of patient data in the NTDB used by this study represents one of the many advantages to performing this retrospective analysis. The evaluation and investigation of the variables included in the database serves as a platform to gather the information available and analyze it for a more comprehensive understanding of association or dissociation within variables. The national database allows for a more homogenous distribution of patient population, which adds to the strength of this study by preventing possible selection or geographical bias. Furthermore, the study design eliminates the possibility of loss of patient follow-up and eventual loss of vital data. In addition, one of the major advantages includes the relatively inexpensive nature of the study to yield informative results. Having multiple variables on each case such as length of stay, mechanical ventilation requirement, GCS, and so forth, allows for a better assessment of patient condition and can help decipher any data serving as an outlier.

Given the retrospective nature of this NTDB study, some limitations are present. The most recent available data provided by the NTDB was 2013. Thereby, these data may not be completely representative of current MCC. In addition, the NTDB relies on accurate reporting on the part of each participating hospital, and as a result, is subject to the limitations associated with convenience samples and selection bias. Utilization of the NTDB may also not be representative of all hospitals but rather represents a disproportionate amount of larger hospitals with younger and more severely injured patients. In addition, the data set will not capture those patients who were deemed nonsurvivors by first responders.

Universal helmet laws: A state of the union

Universal helmet laws, first enacted in 1967, have been repealed by most states and continue to remain controversial. According to the Insurance Institute for Highway Safety, there are currently 19 states and the District of Columbia that require universal helmet laws and 28 states which have partial laws requiring helmet use for younger ages. Pennsylvania and Colorado are the most recent states to modify their helmet laws in 2003 and 2007, respectively. Illinois, Iowa, and New Hampshire do not have any helmet laws since the repeal. Despite the overwhelming amount of scientific literature recommending helmet use and the danger of repealing helmet laws, most of the country continues to have partial helmet laws which enforce helmet use only among individuals up to age 21 y.[4-10] Helmet use by riders across all states reportedly falls between 60% and 70%.[7,11-13] In states without helmet laws, use is reported to be as low as 18%.[14] In states with laws, compliance is reported to be up to 72%.[7]

The Center for Disease Control and Prevention assessed the efficacy of helmet laws and found that in states with universal helmet laws, 12 % of those involved in a fatal crash were not wearing a helmet compared with 64% in states with partial laws; 79% of riders in fatal crashes were unhelmeted in states with no helmet laws. Fatally injured riders were significantly more likely to be found without helmets in states with partial or no helmet laws.[9] The Center for Disease Control and Prevention report also sites that on repealing state helmet laws or opting for a partial law, helmet use decreases and motorcycle-related deaths, injuries, and costs increase.[9]

However, advocacy groups have cited multiple reasons to contest universal helmet laws. These include increased severity of cervical injuries due to presence and weight of the helmet, decreased hearing ability, decreased peripheral vision, and limiting personal freedom and individual liberty.[15] Although use of a helmet reduces peripheral vision by 20°, it does not have an impact on the collision rates or safety of riders.[15,16] Many prior studies have dismissed the claims that helmets contribute to neck injuries; although, one study from

Sweden identified fatigue associated with helmet use but concluded that the benefits significantly outweighed possible fatigue.[15] The Department of Transportation National Highway Traffic Safety conducted a study to evaluate the effects of helmets on hearing and vision and concluded that helmet use did not significantly affect ability to see or hear nearby traffic.[16]

Multiple states have examined their experiences with motorcycle-associated trauma before and after helmet law repeal. In Illinois, one of the states with no current helmet laws, unhelmeted patients were more likely to have head (51%) and spine injuries (8%) when compared with helmeted patients, who had rates of 30% and 4%, respectively.[14] Michigan saw a dramatic increase in unhelmeted riders, from 7% to 28%, after the state's 35-year-old mandatory helmet law was repealed in 2012. In that same time period in Michigan, fatalities involving unhelmeted individuals rose from 14% to 68% and crash survivors had higher rates of in-patient mortality, ISS, need for ICU stay, and ventilatory support compared with helmeted riders.[10] Pennsylvania, which is also one of the more recent states to repeal its helmet laws in 2003, showed a similar trend in regard to risks associated with unhelmeted MCCs. After the repeal, helmet use in Pennsylvania decreased from 82% to 58%, mortality due to head injuries increased 66%, and deaths due to nonhead related injuries increased by 25%.[5] A similar scenario has been reported in states like Arkansas, Texas, Washington, and Florida among others.[1,8,13,17]

The cost of unhelmeting

In this series, unhelmeted patients were more likely to be uninsured or carry government-based (Medicare/Medicaid) insurance when compared with helmeted patients. This can have several implications. Unhelmeted patients are more likely to incur higher immediate hospitalization costs because of more severe injuries and likely have higher long-term financial burdens because of disability. In the setting of their uninsured or underinsured status, this directly translates to increased societal economic burden.

States without universal helmet laws have been shown to have a greater health care expenditure because of the nature of injuries sustained and level of hospital care required by unhelmeted riders.[18] Literature has consistently shown a strong trend toward increased use of public funds for uninsured, unhelmeted patients.[7,14,18] Helmet use has shown to decrease the mean hospitalization cost by more than $6000 per patient.[2] Iowa, a state with no helmet laws, has indicated cost savings of up to $20,000 per helmeted patient.[4] A recent meta-analyses of the past 20 y indicated that unhelmeted patients require $12,239 more in hospital care compared with helmeted patients.[19] Dua *et al*. conducted a statistical life analysis to determine the cost burden on society due to an unhelmeted crash victim. The study reported a loss of $2.2 billion in health care and societal costs nationally because of individuals who do not wear helmets. Using value of statistical life analyses, the per capita cost of fatality was determined to be greater than $800,000. In addition to the $2.2 billion cost savings, the statistical value added on by each fatality prevented is estimated to be $2.4 billion, which indicates for a $4.6 billion yearly gain.[18]

Conclusions

In summary, our study using the National Trauma Data Bank supports the use of helmets in motorcycle riders. In this series, which included data from 10,345 patients involved in MCCs, unhelmeted MCC patients had more severe injuries (increased ISS, decreased GCS), higher rates of ICU admissions, higher rates of mechanical ventilation, and increased in-hospital mortality when compared with helmeted MCC patients. The unhelmeted patients were also more likely to be uninsured or government-insured. Our analysis suggests the need to revisit the issue regarding laws requiring protective headwear while riding motorcycles because of the individual and societal impact. Helmet use is truly a societal issue, as the cost burden is endured by the public, and must be addressed in a nationwide policy reform of helmet laws.

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Authors' contribution: M.L.S. and S.M. designed the study. P.B.P. and C.A.S. performed the acquisition of data, and the analysis/interpretation of data. P.B.P. wrote the article. All authors were involved in providing feedback on the article.

Disclosure

No authors have conflicts of interest to report.

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