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Association of State Helmet Laws with Helmet Use and Injury Outcomes in Motorcycle Crashes

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Brief Title: State Helmet Laws and Helmet Usage

Background:

Helmet laws vary by state. North Carolina (NC) requires all motorcyclists to be helmeted, while South Carolina (SC) requires helmets only for drivers under 21 years of age. We examined helmet use data and outcomes among motorcycle crash (MCC) patients evaluated at a level I trauma center with a catchment area spanning the two states.

Study Design:

A retrospective cohort study was conducted of all adult MCC victims evaluated by the trauma department at an ACS-verified Level 1 Trauma Center between July 2012 and July 2022. Helmet usage was compared by state, and outcomes were compared by helmet status.

Results:

A total of 2,196 patients were evaluated following MCC; 86.3% were helmeted. Patients injured from NC were more likely to be helmeted as compared to SC (94 vs 52%, respectively, $p<0.001$). Helmeted patients had a lower Injury Severity Score (13.6 vs 16.0, $p=0.001$). Helmeted patients were more likely to be discharged from the ED (13 vs 10%) and were less likely to be admitted to the ICU (25% vs 39%, $p<0.001$). In-hospital mortality for helmeted patients was 4% vs 7% in unhelmeted patients ($p=0.05$).

Conclusion:

Patients from NC were more likely to be helmeted as compared to SC. Unhelmeted patients had more severe injuries, were more likely to be admitted and require ICU-level care.

Keywords: Motorcycle collision, helmets, trauma, injury prevention

Background:

Road traffic injury is the 8th leading cause of death worldwide and the leading cause of death among children and young adults.[1] Universal helmet laws increase helmet use and reduce brain injury and death caused by motorcycle collisions (MCC).[2,3] Despite these benefits, only 19 of 50 states have adopted universal helmet laws.[4] Lawmakers are often pressured, sometimes with success, to repeal these laws.[5,6] Fifty years ago, 47 states had mandatory helmet laws, and the national trend has been towards repeal which is contradictory to trends in automobile safety law and global helmet law.[7]

North Carolina's (NC) universal helmet law has been under threat of repeal every two years for the last decade in the NC House of Representatives (HOR).[8] These repeals have failed in part due to testimony from trauma and emergency medicine physicians. In particular, trauma surgeons have presented short-term trauma data on the disparate outcomes of helmeted and unhelmeted drivers to the NC HOR, contributing to repeal prevention.

In order to gather regional data to inform state policy and contribute to future repeal prevention, we conducted a ten year retrospective cohort study of motorcycle crash victims presenting to the busiest trauma center in NC over the last decade. The level 1 trauma center is uniquely positioned with a catchment area including one state with a universal helmet law (NC) and a second state (South Carolina -SC) with only a partial law requiring riders under 21 to be helmeted. The objective of this study is to determine 1) the influence of disparate helmet laws on helmet utilization among MCC victims presenting to the level 1 trauma center and 2) the effect of helmet status on post-emergency department outcomes.

Methods:

A retrospective cohort study was conducted of all adult motorcycle collision (MCC) victims evaluated by the trauma department at an American College of Surgeons-verified level 1 trauma center between July 2012 and July 2022. Patient demographics, injury features, and outcomes were obtained from a prospectively maintained trauma registry. All adult patients evaluated by the trauma service following an MCC were included. Patients with a home state outside of the Carolinas and those with unknown helmet status were excluded. Children (<18 years old) were additionally excluded. Outcomes were compared by helmet status. The primary outcome was helmet use by state. Both home state and state of injury were analyzed. Secondary outcomes included hospital and intensive care unit (ICU) length of stay (LOS), injury severity, hospital cost, disposition and mortality compared by helmet status at the time of injury. Helmet use and outcomes among patients 21 years of age and younger were analyzed as this group is legally required to be helmeted in both states. Subgroup analyses were performed of outcomes based on gender, race, and ethnicity.

Operational Definitions

Home state is the state of the patients home address. Injury state is the state where the injury occurred. Injury Severity Score (ISS) is a measure of injury severity taking into account the degree of injury to the head, chest, abdomen and other body systems ranging from 0 to 75. Abbreviated Injury Scores (AIS) reflect the injury severity of a specific body system such as the abdomen and range from 0 to 6. A higher ISS or AIS score indicates a more severe injury.

Statistical Analyses

Data were analyzed using standard statistical methods, appropriate to the type of variable and normality of the data. Descriptive statistics including means, standard deviation, counts, percentages and five-point summary statistics were used to describe the study population on all variables. Multivariate linear and logistic regression was used to control for confounders for continuous and categorical variables, respectively. Right skewed variables (LOS, ICU LOS, and ventilator days) were analyzed using the Mann-Whitney U test and Kruskal Wallis tests. To control for confounders, a Generalized Linear Model with Gamma Distribution was used for right skewed variables. A p-value of <0.05 was used for all significance determinations. STATA (BE 17.0, StataCorp LLC, College Station, TX) was used to complete statistical analyses [9].

Results:

A total of 2,681 patients were evaluated following MCC between 2012 and 2022. Seventy-four patients were excluded due to having homes states outside of NC and SC. Helmet data was available for 2,196 (84%) patients; of which 86% were helmeted (Table 1). The majority of patients were male (91%) and white (73%). Helmeted patients more often had commercial insurance and were less often uninsured (Table 1).

Among the 411 patients with unknown helmet status, 80% were discharged from the ED. Those with unknown helmet status had lower Head/Neck, Chest and Abdomen AIS (Supplemental Digital Content 1, http://links.lww.com/JACS/A470). Patients with unknown helmet status were relatively younger and more often Black, though these were not statistically significant when controlling for ED disposition (Supplemental Digital Content 1-3, http://links.lww.com/JACS/A470). Home and injury state did not differ between those with

known and unknown helmet status (Supplemental Digital Content 1, http://links.lww.com/JACS/A470).

Primary Outcome: Helmet Status by State

Eighty-one percent of patients had a home state in NC, and 19% in SC. Forty-seven percent of patients with a home state of SC were unhelmeted at the time of injury, as compared to 5.8% of patients from NC ($p < 0.001$) (Figure 1). State of injury was known for 64% of patients, of which 89% occurred in NC and 11% in SC. Four percent of patients injured in NC were unhelmeted, as compared to 49% of patients injured in SC ($p<0.001$).

Secondary Outcome: Patient Outcomes by Helmet Status

Unhelmeted patients had a higher ISS, lower initial Emergency Department Glasgow Coma Scale (GCS), and higher Head/Neck AIS as compared to helmeted patients (Table 2, Figure 2). Helmeted patients were more likely to be discharged from the ED and were less likely to be admitted to the ICU. No difference in average hospitalization cost was found between helmeted and unhelmeted patients (Table 2). Though hospital length of stay (LOS) did not differ by helmet status, unhelmeted patients had longer ICU LOS and more ventilator days (Table 2). In hospital mortality for helmeted patients was 4.4% vs 7.0% in unhelmeted patients ($p=0.05$).

Subgroup Analysis: Patients 21 Years and Younger

One hundred and forty-six patients were 21 years old or younger. This age group is legally required to wear helmets in both states. Overall, patients 21 years old or younger were helmeted at an equal rate to those over 21 (86.3% vs 86.3%, $p=0.99$). However, patients aged 21 years and younger with a home state of SC were significantly more likely to be unhelmeted at

the time of injury as compared to those from NC (33% vs 10%, p=0.002). Likewise, patients injured in SC in this age group were more likely to be unhelmeted (36 vs 10%, p=0.013).

Unhelmeted patients in the 21 and younger cohort had lower ED GCS, higher Head/Neck AIS scores, and more ICU and ventilator days as compared to helmeted patients in this age group (Table 3).

Subgroup Analyses: Gender, Race, Ethnicity

Patients with a home state of SC were more likely to be women (12.3% vs 8.7% from NC, 0.01), more often White (79.3% vs 71.5%) and less often Black (15.7% vs 21.3%, p =0.02) or Hispanic (1.2% vs 4.4%, p=0.002) as compared to those from NC. Overall, women were less likely to be helmeted (Table 1), though this was no longer true when controlling for home state in logistic regression (Supplemental Digital Content 4, http://links.lww.com/JACS/A470).

Patient outcomes by gender, race and ethnicity are detailed in Supplemental Digital Content 5 (http://links.lww.com/JACS/A470). Patient outcomes did not vary significantly by gender. Hispanic patients had lower Head/Neck AIS scores as compared to non-Hispanic patients (0.5 vs 0.9, p=0.03, Supplemental Table 5, http://links.lww.com/JACS/A470). This remained true when controlling for helmet status and home state in multivariate linear regression (p=0.046, Supplemental Digital Content 6, http://links.lww.com/JACS/A470). Hispanic patients had fewer ICU days though this did not remain significant when controlling for helmet status and home state (Supplemental Digital Content 7, http://links.lww.com/JACS/A470).

Black patients had a lower average ISS than patients of other races (12.4 vs 14.5 of White patients, p=0.003) which remained true when controlling for helmet status and home state (p=0.001, Supplemental Digital Content 8, http://links.lww.com/JACS/A470). Black patients were also more often discharged home from the ED (18.3% vs 10.4% of White patients), and

less often admitted to the ICU (21.7%, vs 29.0%, p<0.001) (Supplemental Digital Content 5, http://links.lww.com/JACS/A470). These findings remained significant controlling for helmet status and home state in multivariate logistic regression (p <0.001 and p=0.002, respectively, Supplemental Digital Content 9 and 10, http://links.lww.com/JACS/A470). Hospital and ICU LOS and ventilator days also varied by race, though this was no longer significant when controlling for home state and helmet status (Supplemental Digital Content 5, 11, 12, and 13, http://links.lww.com/JACS/A470).

Discussion:

Patients from NC were significantly more likely to be helmeted as compared to patients from SC. Although, SC law requires motorcyclists under the age of 21 to be helmeted, helmet use among patients in this age group was also significantly reduced among South Carolina riders. Unhelmeted patients had more severe injuries, had more brain injuries, were more likely to require hospital and ICU admission, and were less often discharged home.

We found significantly better outcomes among helmeted patients in our cohort. The safety benefits of helmets are well documented in the literature. A 2008 Cochrane review found that helmet use consistently and significantly reduces the risk of death and head injury in motorcycle crashes. Based on the highest quality evidence the Cochrane review estimates a reduced risk of death of 42% and reduced risk of head injury of 69% among helmeted riders.[2] Likewise, a retrospective National Trauma Data Bank study examined 270,000 motorcycle collision victims between 2007 and 2014 and found that unhelmeted patients had a higher incidence of head injury, cervical spine injury and death than helmeted patients.[10]

Universal helmet laws increase helmet utilization. The National Occupant Protection Use Survey found that cyclists in states that have universal helmet laws were much more likely to wear DOT-compliant helmets (81.5% vs 56.2%).[11] Increased perception of the presence of law enforcement is also a positive predictor of helmet usage resulting in increased use on highways, during weekdays and daylight hours.[12–14] Repealing helmet laws has been found to result in reduced helmet utilization and a rise in head injuries in states such as Arkansas, Texas and Michigan.[5,15,16] Therefore, the CDC recommends state helmet laws as a means to reduce motor cycle crash mortality.[17]

Heterogeneity exists among studies examining the influence of demographic factors and helmet use.[3] In our cohort, no differences in helmet usage existed by gender, race or ethnicity when controlling for state of injury. We observed lower injury severity scores and reduced need for admission among black patients as compared to other races, which remained true when controlling for home state and helmet status. Helmeted drivers more often had commercial insurance while unhelmeted drivers were more often uninsured. Private insurance has been associated with increased helmet use according to a 2007-2010 National Trauma Database study.[18]

We did not find a difference in helmet usage by age group. However, state differences in helmet use persisted among young patients. Despite SC requiring helmet use among patients under 21 years of age, a third of patients in this age group from SC were unhelmeted as compared to 10% from NC. Reduced helmet usage in this young cohort was also associated with poorer outcomes with more severe brain injuries and more ICU admissions. A systematic review and meta-analysis on adolescent helmet use under age-specific vs. universal helmet laws found greater adolescent compliance under universal helmet laws.[19] Universal helmet laws are

estimated to reduce helmet noncompliance by two-thirds as compared to age-specific laws.[19] A "mixed messaging" effect is felt to contribute to this discrepancy. States not requiring helmets for all riders increases the perception that helmets do not offer safety benefits.[20,21] Universal helmet laws are more effective at encouraging helmet use among young riders than laws only targeting their age group.

While the evidence is clear that helmets have substantive safety benefits, the American Motorcycle Association and other cyclists groups have led successful campaigns to eliminate state helmet laws, arguing that these laws are paternalistic and impinge on personal freedoms.[7] Advocates are necessary to protect helmet laws. Surgeons have an intimate understanding of the injuries and outcomes among MCC victims and are well-positioned to advocate for evidence-based policies promoting injury prevention. As such, the American College of Surgeons has consistently opposed legislation to repeal universal helmet laws.[22] The National Highway Fatality and Injury Reduction Act of 1989, a bill tying federal highway funding to universal helmet laws, was initially announced at the American Trauma Society.[7] As helmet laws are threatened at the state level, physicians and surgeons can provide unique perspective to lawmakers to promote the protection of these laws at a local level.

This work has various limitations. We report data from a cohort of patients evaluated at a Level I trauma center, therefore, our data do not capture patients who died on scene or prior to arrival to our trauma center. On the other end of the spectrum, we also do not capture those without injuries requiring transport to a trauma center. While the catchment area of the trauma center includes both NC and SC, the center is located in NC. Thus, it is possible that patients injured in SC were less likely to be transported to the Level I center for minor injuries as compared to those injured in NC in close vicinity of the hospital. This could introduce

confounding contributing to the reduced helmet usage and worse outcomes seen among those in SC. Further, helmet status was unknown for 15.8% of patients. Home and injury state did not differ between those with and without known helmet status, so this likely did not have a large influence on the primary outcome of helmet use by state. However, those with unknown helmet status were much more often discharged from the ED and had more favorable outcomes overall. These missing data may have influenced our findings on the effect of helmet usage on outcomes though it is difficult to say in which direction or to what degree.

Conclusion

We found that unhelmeted patients incurred more severe injuries and were more likely to be admitted and require ICU-level care. Patients injured in NC where a universal helmet law exist were significantly more likely to be helmeted as compared to patients injured in SC, where only riders under 21 are required to be helmeted. This trend persisted even among patients under 21. Additionally, unhelmeted patients were more likely to be publicly funded, passing costs along to taxpayers. Our data suggest that repeals to NC's universal helmet law would result in reduced helmet utilization and worse outcomes for these trauma patients. In anticipation that repeal attempts will continue to be introduced to the NC HOR, we plan to utilize these findings to support protection of the universal helmet law in NC and provide a resource for other states in efforts to reduce injury burden related to MCC.

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Figure 1: Helmet use by home state.

Figure 2: Box plot displaying Injury Severity Score (ISS) by helmet status at the time of injury.

Precis

A decade of motorcycle collision data from an American College of Surgeons-verified Level I Trauma Center positioned at the border of 2 states with differing motorcycle helmet laws was queried. Helmeted patients had reduced injury severity. State helmet laws were found to significantly influence helmet usage among motorcyclists.

Table 1: Patient Demographic Features by Helmet Status

Demographic	Total (n = 2196)	Helmeted (n = 1896)	Not helmeted (n = 300)	p Value
Age, y, mean (SD)	41.6 (14.3)	41.8 (14.4)	40.4 (13.8)	0.11
Sex, male, %	90.5	91.2	86.3	0.002
Race, %				0.30
White	73.0	72.7	75.0	
Black	20.2	20.1	21.0	
Asian	0.8	0.8	1.0	
Ethnicity (Hispanic)	3.7	4.1	1.3	0.06
Home state, %				<0.001
NC	81.1	88.5	34.3	
SC	18.9	11.5	65.7	
Injury state, %				<0.001
NC	89.3	94.0	41.2	
SC	10.7	6.0	58.8	
Payor, %				0.03
Commercial	67.6	68.6	61.3	
Medicaid	4.8	4.8	4.7	
Medicare	5.8	5.4	8.3	
Uninsured	17.0	16.3	21.7	

Table 2: Patient outcomes by helmet status

Outcomes	Total	Helmeted	Not Helmeted	p Value
ISS, mean (SD)	13.9 (11.3)	13.6 (11.2)	16.0 (11.3)	<0.001
ED GCS, mean (SD)	13.4 (3.7)	13.6 (3.5)	12.3 (4.6)	<0.001
Head/Neck AIS, mean (SD)	0.9 (1.4)	0.7 (1.3)	1.7 (1.7)	<0.001
Chest AIS, mean (SD)	1.2 (1.4)	1.2 (1.4)	1.3 (1.4)	0.21
Abdomen AIS, mean (SD)	0.6 (1.1)	0.6 (1.1)	0.6 (1.1)	0.82
ED disposition, %				<0.001
Floor	49.5	50.9	41.0	
ICU	26.9	24.9	39.3	
OR	9.4	9.5	8.7	
Discharged home	12.3	12.8	9.7	
Morgue	1.4	1.5	0.7	
Total hospital d, median (IQR)	3 (1-8)	3 (1-8)	3 (1-8)	0.31*
Total ICU d, %				<0.001*
0	65.9	68.2	51.6	
1	2.5	2.1	5.2	
2-4	17.1	16.3	22.1	
≥5	14.5	13.4	21.1	
Total ventilator d, %				<0.001*
0	80.1	82.0	68.5	
1	2.5	2.4	2.9	
2-4	8.7	7.7	15.3	
≥5	8.7	8.0	13.3	
Discharge disposition, %				0.14
Death	4.8	4.4	7.0	

Home	73.4	73.7	71.3	
Home health	4.6	4.9	3.3	
SNF or LTAC	4.3	4.5	3.0	
Rehab	10.9	10.7	12.3	
Other	1.9	1.7	3.0	
Charge, $, median (IQR)	63,662 (26,702, 146,942)	63,571 (26,490, 142,144)	66,196 (32,086, 154,978)	0.28*

*Mann-Whitney U test

AIS, Abbreviated Injury Scale score; ED GCS, emergency department Glasgow Coma Scale; IQR, interquartile range; ISS, Injury Severity Score; LTAC, long term acute care; OR, operating room; SNF, skilled nursing facility.

Table 3: Demographics and Outcomes Among Patients 21 Years Old and Younger

Demographics and Outcomes	Total (n = 146)	Helmeted (n = 126)	Not helmeted (n = 20)	p Value
Sex, m, %	91.1	92.9	80.0	0.06
Race, %				0.93
White	77.4	77.0	80.0	
Black	11.6	11.1	15.0	
Asian	1.4	1.6	0	
Ethnicity (Hispanic), %	6.8	7.1	5.0	0.92
Home state, %				0.002
NC	83.6	87.3	60.0	
SC	16.4	12.7	40.0	
Injury state, %				0.05
NC	88.2	91.3	66.7	
SC	11.8	8.7	33.3	
ISS, mean (SD)	13.4 (11.5)	13.0 (11.4)	15.9 (11.9)	0.31
ED GCS, mean (SD)	13.4 (3.7)	13.7 (3.3)	11.0 (5.2)	0.002
Head/Neck AIS, mean (SD)	0.8 (1.4)	0.7 (1.3)	1.6 (1.7)	0.006
Chest AIS, mean (SD)	1.1 (1.3)	1.1 (1.3)	1.0 (1.1)	0.99
Abdomen AIS, mean (SD)	0.8 (1.3)	0.8 (1.2)	1.1 (1.5)	0.29
ED Disposition, %				0.14
Floor	50.7	53.2	35.0	
ICU	22.6	19.0	45.0	
OR	11.0	11.1	10.0	
Home	15.1	15.9	10.0	
Morgue	0.7%	0.8%	0	

Total hospital d, median (IQR)	2 (1-6)	2 (1-6)	1 (3-7)	0.61*
Total ICU d, %				0.01*
0	71.3	75.4	45.0	
1	3.3	2.3	10.0	
2-4	17.3	15.4	30.0	
≥5	8.0	6.9	15.0	
Total Ventilator d, %				0.01*
0	82.7	86.2	60.0	
1	1.3	0.8	5.0	
2-4	10.7	8.5	25.0	
≥5	5.3	4.6	10.0	
Discharge disposition, %				0.42
Death	3.4	3.2	5.0	
Home	82.2	83.3	75.0	
Home Health	4.1	4.8	0	
SNF or LTAC	1.4	0.8	5.0	
Rehab	8.2	7.1	15.0	
Other	0.7	0.8	0	
Charge, $, median (IQR)	63,227 (23,639, 128,764)	60,080 (22,645, 121,572)	66,380 (28,115, 164,199)	0.53*

*Mann-Whitney U test

AIS, Abbreviated Injury Scale score; ED GCS, emergency department Glasgow Coma Scale; IQR, interquartile range; ISS, Injury Severity Score; LTAC, long term acute care; OR, operating room; SNF, skilled nursing facility.

Figure 1

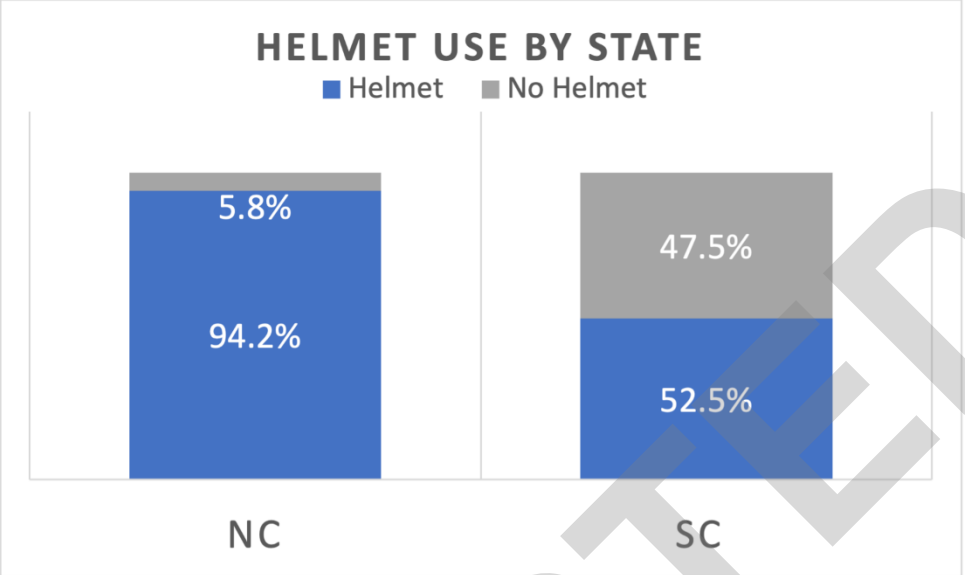

Figure 2