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INTRACRANIAL INJURY AND MORTALITY ASSOCIATED WITH MOTORCYCLE-RELATED HOSPITALIZATIONS: DIFFERENCES IN INCIDENCE AND COSTS ON THE BASIS OF UNIVERSAL MOTORCYCLE HELMET USE LEGISLATION IN THE UNITED STATES

BY

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INTRACRANIAL INJURY AND MORTALITY ASSOCIATED WITH MOTORCYCLE-RELATED HOSPITALIZATIONS: DIFFERENCES IN INCIDENCE AND COSTS ON THE BASIS OF UNIVERSAL MOTORCYCLE HELMET USE LEGISLATION IN THE UNITED STATES

BY

Brenda Marie Parker
MPH, Emory University, 2011
PharmD, The University of Georgia, 2005

Thesis Committee Chair: Walter Burnett, PhD

An abstract of
A Thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements of the degree of
Master of Public Health in the Career MPH program
2011

ABSTRACT

Intracranial Injury and Mortality Associated with Motorcycle-related Hospitalizations: Differences in Incidence and Costs on the Basis of Universal Motorcycle Helmet Use Legislation in the United States

BY
Brenda Marie Parker

Objectives: To compare the incidence of intracranial injury and in-hospital mortality as well as costs associated with motorcycle-related hospitalizations on the basis of universal motorcycle helmet legislation in the United States.

Methods: A retrospective cross-sectional ecological database analysis was performed using all hospitalizations with a supplementary classification of external causes of injury and poisoning code for motorcycle-related crashes from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample for the years 2005 to 2007. Differences in intracranial injury and mortality rates as well as costs were compared between two groups defined by the presence or absence of universal motorcycle helmet use legislation in the US.

Results: Over the analysis period, there were 87,616 injury-related hospital discharges as a result of motorcycle-related crashes. In the absence of universal motorcycle helmet use legislation, intracranial injury and in-hospital mortality was 20% and nearly four times more likely to occur, respectively, than in its presence (OR 1.20; 95% CI 1.022-1.418 and OR 3.825; 95% CI 3.061-4.781, respectively). Mean costs associated with hospitalization were higher in the presence of universal legislation than where it was absent, \$60,478 and \$23,243, respectively ($p<0.0018$).

Conclusions: Additional research and advocacy of other public health models and injury prevention strategies to complement motorcycle helmet use legislation is warranted to increase the likelihood that Congress may uphold any future legislation that encourages state adoption of universal motorcycle helmet use legislation as persuasion of state legislatures to maintain or re-enact such legislation based on fact alone has, to-date, proven futile.

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INTRODUCTION

PROBLEM STATEMENT

Motorcycle-related crashes are associated with a high incidence of head injury and death, which could be significantly reduced with motorcycle helmet use. According to the National Highway Traffic Safety Administration (NHTSA), 7,253 hospitalized motorcyclists were admitted with traumatic brain injury (TBI) from 2003 to 2005, and 5,290 motorcyclists were killed in 2008, accounting for 17 percent of all motorcycle-related hospitalizations and 14 percent of all traffic fatalities, respectively (Cook, Kerns et al. 2009; NHTSA 2009). Of those hospitalized motorcyclists with TBI, 21 percent were unhelmeted; among those fatally injured, 41 percent of motorcyclists and 51 percent of passengers were not wearing motorcycle helmets at the time of the crash (Cook, Kerns et al. 2009; NHTSA 2009). It is estimated that motorcycle helmets saved 1,829 motorcyclist lives in 2008; if all motorcyclists had worn helmets, an estimated 823 additional lives might have been saved (NHTSA 2009).

In 2001, roughly 30,505 hospital admissions were associated with motorcycle injuries and the estimated hospital charges associated with these hospitalizations totaled more than $841 million (Coben, Steiner et al. 2004). In addition to costs related to hospitalizations, there are costs incurred by unhelmeted motorcyclists over and above those wearing helmets as they are significantly more likely to require emergency department care and suffer brain injury that requires discharge to rehabilitation facilities (Hundley, Kilgo et al. 2004; Eastridge, Shafi et al. 2006).

PURPOSE STATEMENT

The purpose of this analysis is to examine the relationship between universal motorcycle helmet use legislation and clinical outcomes, specifically intracranial injury and in-hospital mortality, as well as costs associated with motorcycle-related hospitalizations in the US. Evaluations of head injury or mortality are available in the literature and based primarily on motorcycle helmet use legislation from the local, or state, perspective; this analysis adds to the existing body of evidence a comprehensive evaluation of these outcomes and the national burden associated with each in terms of incidence and costs.

RESEARCH QUESTIONS AND HYPOTHESES

Question: Does universal motorcycle helmet use legislation reduce the incidence of intracranial injury associated with motorcycle-related hospitalizations?

> Null Hypothesis: There is no difference in intracranial injury rates associated with motorcycle-related hospitalizations on the basis of motorcycle helmet use legislation.

Question: Does universal motorcycle helmet use legislation reduce the incidence of in-hospital mortality associated with motorcycle-related hospitalizations?

> Null Hypothesis: There is no difference in in-hospital mortality rates associated with motorcycle-related hospitalizations on the basis of motorcycle helmet use legislation.

Question: Does universal motorcycle helmet use legislation reduce the medical costs of motorcycle-related hospitalizations?

Null Hypothesis: There is no difference in inpatient costs associated with motorcycle-related hospitalizations on the basis of motorcycle helmet use legislation.

SIGNIFICANCE STATEMENT

Opponents of motorcycle helmet use legislation maintain that the decision to wear a helmet is an individual right; however, the impact of the decision to not wear head protection is borne by society. Of motorcycle-related crash victims, roughly half are privately insured; the majority of medical costs for those without private health insurance are paid by the federal government (Cook, Kerns et al. 2009). Of the 68,000 motorcyclists injured in 2002, 42% were unhelmeted; using the average increase in hospital charges of $2451 for motorcyclists not wearing helmets, the total costs associated with not wearing a helmet were over $70 million, with greater than $30 million of that amount not covered by private health insurance (Hundley, Kilgo et al. 2004). In the 1972 case of Simon v. Sargent, a federal court judge declared that requiring motorcyclists to wear a helmet is indeed an issue of public health over individual rights for "from the moment of injury, society picks the person up off the highway, delivers him to a municipal hospital and municipal doctors, provides him with unemployment compensation if, after recovery, he cannot replace his lost job, and, if injury causes permanent disability, assumes responsibility for his and his family's continued subsistence" (*Simon v. Sargent*).

DEFINITION OF TERMS

Motorcyclist: Motorcyclist generally refers to the driver or operator of a motorcycle; however, in the context of this evaluation, motorcyclist is used more broadly to refer to any person, driver or passenger, associated with the operation of a motorcycle.

Motorcycle-related Crash: Motorcycle-related crashes refer to any motor vehicle accident that involves a motorcycle. The categories of motor vehicle accident include traffic and non-traffic, wherein the latter refers specifically to those accidents that do not occur in the operation of the motorcycle on a public highway.

Motorcycle Helmet Use Legislation: Motorcycle helmet use legislation refers to state laws regarding the use of motorcycle helmets and the operation of a motorcycle. There are two types of motorcycle helmet use legislation: partial and universal. Partial motorcycle helmet use legislation refers to a state mandate that applies to some motorcyclists based on criteria such as age, length of time since initial licensure specific to motorcycles or the completion of safety training. Universal motorcycle helmet use legislation is the strictest type of motorcycle helmet use legislation in which the state mandate applies to any and all motorcyclists, requiring that driver or passenger of a motorcycle use motorcycle helmets during the operation of the vehicle.

Intracranial Injury: Intracranial injury is a specific diagnosis that refers to brain injury resulting from external forces.

In-hospital Mortality: In-hospital mortality is the death of a motorcyclist during the hospital stay, i.e. after admission but before discharge. Using the Nationwide Inpatient Sample (NIS), it is impossible to capture deaths at the scene of a motor vehicle crash involving a motorcycle, those occurring en route to or within the emergency room department.

Costs and Charges: Costs are the actual dollar amounts for hospital services or amounts received for payment and charges represent those amounts that the hospital billed for services.

REVIEW OF THE LITERATURE

A review of the literature was undertaken to chronicle motorcycle helmet use legislation in the United States and summarize previous research examining the effectiveness of motorcycle helmets and motorcycle helmet use legislation in terms of injury prevention and economic consequences. Using PubMed, research limited to the adult population, defined as those aged 19 years and older, and published within the past decade was identified based on Medical Subject Headings (MeSH) terms (TABLE 1). The titles and abstracts of all identified research publications were reviewed to assess relevance, and all potentially relevant papers were retrieved and reviewed. For each publication reviewed, the reference lists were examined to find additional germane research not previously identified through the PubMed search, for which the abstract and, if necessary, the publication itself were read to determine its relevance.

With the 1966 National Highway Safety Act, the United States federal government issued a provision for State Highway Safety programs that required states to have motorcycle helmet use legislation in place to highway safety funds. All but three states mandated universal motorcycle helmet use by 1975. Amid numerous appeals to state courts regarding the constitutionality of such legislation and the movement of the Department of Transportation to assess financial penalties on states without motorcycle helmet use legislation in 1976, Congress revoked federal authority to assess penalties linked to motorcycle helmet use legislation. Within four years, over half of all states that had mandated universal motorcycle helmet use changed their laws to allow most, if not all, motorcyclists to ride without helmets (Jones and Bayer 2007).

Following several reports and publications detailing the exponential rise in motorcycle-related deaths and related costs following the repeal of universal motorcycle helmet use legislation and as 34 states adopted mandatory automobile seat belt legislation, the National Highway Fatality and Injury Reduction Act of 1989 was proposed. In 1991, despite opposition from various motorcycle groups, the bill empowering the Department of Transportation to withhold three percent of federal highway funding from states without mandatory motorcycle helmet use legislation passed. However, in 1995, the power of the Department of Transportation to withhold federal funding on the basis of motorcycle helmet use legislation was again repealed. Consequently, and in response to pressure from motorcycle lobby groups, states began to altogether overturn or ease the legislative requirements to apply to some motorcyclists (Jones and Bayer 2007). Currently, according to the Insurance

Institute for Highway Safety, all but 3 states (Illinois, Iowa, and New Hampshire) require some or all motorcyclists to wear helmets (IIHS 2011).

Studies evaluating the relationship of motorcycle helmet use to clinical outcomes report that unhelmeted motorcyclists were significantly more likely to be admitted to the hospital, sustain head injury, die while inpatient and be discharged to rehabilitation facilities than helmeted motorcyclists (Bledsoe, Schexnayder et al. 2002; Hundley, Kilgo et al. 2004; Eastridge, Shafi et al. 2006; Coben, Steiner et al. 2007). Emergency department evaluation was required in a significantly higher number of unhelmeted motorcyclists than helmeted motorcyclists, 78.6% and 73.3%, respectively; similarly, more unhelmeted motorcyclists were admitted to the hospital (Eastridge, Shafi et al. 2006). Motorcycle helmet use independently and significantly reduced the incidence and severity of head injuries, including traumatic brain injury which is associated with longer hospital stays and the leading cause of death in motorcycle-related crashes (Brandt, Ahrns et al. 2002; Lawrence, Max et al. 2002; Hundley, Kilgo et al. 2004; Bledsoe and Li 2005; Eastridge, Shafi et al. 2006; Coben, Steiner et al. 2007; Goslar, Crawford et al. 2008; Mertz and Weiss 2008; Derrick and Faucher 2009). A multivariate analysis accounting for other variables associated with adverse outcomes, i.e. admission systolic blood pressure and the Glasgow Coma Scale score, demonstrated that motorcycle helmet use remained strongly associated with survival, conferring a 16% reduction in mortality odds (Croce, Zarzaur et al. 2009). Lastly, there was a significant difference between unhelmeted and helmeted motorcyclists in terms of discharge to rehabilitation facilities, 15.6% and 12.4%, respectively (Hundley, Kilgo et al. 2004).

Unsurprisingly, studies evaluating the relationship of motorcycle helmet use and costs have demonstrated a similar positive correlation in that costs and charges associated with hospitalization and rehabilitation were higher in unhelmeted motorcyclists, of which has been attributed to head injuries (Bledsoe, Schexnayder et al. 2002; Brandt, Ahrns et al. 2002; Hundley, Kilgo et al. 2004; Eastridge, Shafi et al. 2006; Coben, Steiner et al. 2007). Unhelmeted motorcyclists tend to be underinsured, having less private insurance and more government-funded, i.e. Medicare or Medicaid, or no insurance coverage at all, the latter two of which, characteristically, were associated with significantly higher unreimbursed charges (Bledsoe, Schexnayder et al. 2002; Brandt, Ahrns et al. 2002; Lawrence, Max et al. 2002; Hundley, Kilgo et al. 2004; Derrick and Faucher 2009). As costs and unreimbursed charges are significantly more in unhelmeted motorcyclists, the short- and long-term economic burden is shifted to the healthcare system and, ultimately, society in terms of healthcare costs incurred as well as lost earnings and tax revenues resulting from disability or death (Brandt, Ahrns et al. 2002; Hundley, Kilgo et al. 2004; Knudson, Schermer et al. 2004; Croce, Zarzaur et al. 2009; Derrick and Faucher 2009).

Numerous population-based studies have compared clinical outcomes between states with differing motorcycle helmet use legislation, finding that motorcycle helmet use legislation increased the use of motorcycle helmets, decreased the incidence and severity of head injuries, length of stay as well as discharge to rehabilitation facilities and reduced in-hospital mortality (Auman, Kufera et al. 2002; Hotz, Cohn et al. 2002; Norvell and Cummings 2002; Bledsoe and Li 2005;

Coben, Steiner et al. 2007; Houston and Richardson 2008; Mayrose 2008; Croce, Zarzaur et al. 2009; Dee 2009; French, Gumus et al. 2009). In addition, there have been several single-state studies evaluating the impact of motorcycle helmet use legislation changes; when states repealed universal motorcycle helmet use legislation, helmet use decreased while hospitalizations, fatalities, head injury severity and overall incidence as well as primary reason for admission and subsequent discharge to rehabilitation facilities increased (Vaca and Berns 2001; Auman, Kufera et al. 2002; Bledsoe, Schexnayder et al. 2002; Hotz, Cohn et al. 2002; Christian, Carroll et al. 2003; O'Keeffe, Dearwater et al. 2007; Mertz and Weiss 2008) and, when states reinstated legislation, the converse occurred (Muller 2004; Kyrychenko and McCartt 2006). Analogous to the trends in the aforementioned events, population and single-state studies estimating the economic consequences associated with legislation repeal found that costs increased significantly post-repeal and that minimum medical insurance coverage requirement of $10,000 imposed by some states, e.g. Texas and Florida, is insufficient to cover mean treatment costs ranging from $30,000 to over $40,000 (Vaca and Berns 2001; Coben, Steiner et al. 2007; O'Keeffe, Dearwater et al. 2007; Mertz and Weiss 2008; Dee 2009; Derrick and Faucher 2009).

METHODS

OVERVIEW

A retrospective cross-sectional ecological database analysis was conducted to compare incidence rates of intracranial injury and in-hospital mortality between two groups defined by the presence or absence of universal motorcycle helmet use legislation in the US. A cross-sectional design was used in this analysis as the data are a representative subset of motorcycle-related hospitalizations used to test the relational hypotheses of legislation and clinical outcomes and economic measure; furthermore, an ecological approach was employed as the outcomes of the analysis are of interest in terms of motorcycle use legislation from a national perspective and the unit of analysis is the hospital stay rather than person or patient. Retrospective databases contain large amounts of data and data elements that are necessary for statistical power and for the analysis of interest; the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) represents nearly 90% of all discharges in the US, characterizes hospitalizations by ICD-9-CM codes and contains utilization and cost data.

According to the Code of Federal Regulations Title 45 Section 46.101 subparagraph (b)(4), IRB approval is not needed for publicly available datasets or those that maintain patient anonymity. Both requirements are met by the NIS dataset; as such, the Emory Institutional Review Board (IRB) waived this research.

PATIENT SELECTION

All hospitalizations with a supplementary classification of external causes of injury and poisoning code for motorcycle-related crashes (codes E810-E825, where fourth digits two and three identify the injured person(s) as the motorcyclist and/or passenger on motorcycle from the International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]) were included in the analysis (Appendix 1).

DATA SOURCE

Data from the HCUP NIS for the years 2005 through 2007 was analyzed for this study. The NIS, conducted annually by the Agency for Healthcare Research and Quality (AHRQ), is a nationally representative sample survey of US community hospitals that contains clinical and resource use information for approximately eight million inpatient hospital stays from over 1,000 hospitals in 40 states. The NIS is a stratified, single-stage cluster sample in which a stratified random sample of hospitals that approximates 20% of all US community hospitals, for which all discharges are included in the final sample.

The HCUP application and data use agreement are required to purchase NIS datasets. The data use agreement binds the user to the data protections put forth in the Health Insurance Portability and Accountability Act (HIPAA). The NIS is provided on two CD-ROMs that include fixed-width ASCII formatted files. The first CD-ROM contains the Inpatient Core and Hospital Weights files. The Inpatient Core file is an inpatient discharge-level file containing data for 100% of the discharges from the sample of hospitals in participating states; the unit of observation is the inpatient stay record. The Hospital Weights file contains one observation for each hospital included in the NIS with weight, variance and linkage data elements; the unit of observation is the hospital. The second CD-ROM contains the Disease Severity Measures and Diagnosis and Procedure Groups File; however, these sources of data were not used in this analysis.

The Cost-to-Charge Ratio (CCR) files contain hospital-specific cost-to-charge ratios based on all-payer inpatient costs obtained from hospital accounting reports collected by the Centers for Medicare and Medicaid Services (CMS). The CCR files are required to transform charge information within the Inpatient Core file, representing the amount that hospitals billed for services, into costs that reflect how much hospital services cost or the specific amounts that hospitals received in payment. Upon merging the CCR files with total charges in the Inpatient Core file, the costs represented by the newly created variable include operating and capital-related costs.

The Clinical Classifications Software (CCS) for ICD-9-CM is a diagnosis and procedure categorization tool that combines ICD-9-CM codes into a limited number of clinically meaningful categories. The CCS consists of two related classification systems – a single-level and multi-level system. The single-level system groups diagnoses into mutually exclusive categories while the multi-level system groups the single-level categories into broader categories. A SAS summary program is provided by AHRQ that generates a frequency report of the CCS multi-level categories for the primary diagnoses.

Each HCUP NIS Inpatient Core, further referred to as Core, file for years 2005, 2006 and 2007 was loaded into SAS 9.2 using the electronic SAS load program provided by AHRQ. The CCR files for the respective years were then loaded into SAS using the electronic SAS load program; however, HOSPID was recognized as a character variable and had to be changed in order to merge with the Core files where HOSPID is a numeric variable. The two datasets, Core and CCR, were merged into new datasets for each year. Individual ICD-9-CM clinical diagnoses were combined using the CCS into broad, mutually exclusive groups within each dataset. Due to system limitations for analyses, the NIS files were subset to inpatient stays for motorcycle-related crashes and new variables for descriptive and inferential analysis were created. Because the creation of a subset population may exclude a sample hospital and thus lead to incorrect standard errors, the subset file included 'dummy' observations for each hospital in the NIS. Lastly, the three separate files were merged to create one final analytic file.

STUDY MEASURES

The policy variable of interest, LAW, was created as a dichotomous variable (0/1) by which states were grouped based on the presence of universal motorcycle helmet use legislation according to the Insurance Institute of Highway Safety (IIHS 2011). The decision to combine those states with no legislation and those with partial use legislation was supported by previous observational findings that use rates between the states were similar (Branas and Knudson 2001; Coben, Steiner et al. 2007).

The clinical outcome variables of interest, intracranial injury (IC) and in-hospital mortality (ALIVE), were created as binary variables (0/1) to indicate occurrence of the respective event. Intracranial injury was identified using the CCS diagnosis variables where intracranial injury was the diagnosis; all 15 diagnosis fields were included as there is no distinction in terms of the outcome between primary or secondary designations. The variable DIED is a variable that reflects in-hospital death as the patient disposition; a new variable where in-hospital mortality was represented as its inverse was created to in order to facilitate the ease of analysis and avoid potential coding errors.

Inpatient costs were captured as a new variable (COSTS) created by merging the existing total charges variable with the group average all-payer inpatient cost/charge ratio, GAPICC. It was decided to use the group average rather than the hospital-specific cost-to-charge as the weighted group average is available for all hospitals within the dataset.

Demographic variables contained within the NIS dataset were included for descriptive and inferential statistical purposes. Age was included as both a continuous (AGE) and categorical variable (AGE1), with the latter defined as pediatric (aged ≤ 20 years), adult (aged 21-64 years) and elderly (aged ≥ 65 years). Gender was included as defined in the NIS data, FEMALE (0/1); RACE was not included in this analysis due to the large number of missing observations (n=19,566). The median household income for patient's zip code (ZIPINC_QRTL), grouped in quartiles of $1-$35,999, $36,000-$44,999, $45,000-$58,999 and $59,000 or more, and primary expected payer, (PAY1), identified as Medicare, Medicaid, private including HMO, self-pay, no charge and other, were analyzed and reported unchanged .

Likewise, clinical variables were identified for descriptive and inferential analysis, including admission, principal diagnosis, disposition, discharge and length of stay. There were two variables in the NIS dataset that described admission – source (ASOURCE) and type (ATYPE) – that were included in the analysis. In addition to the clinical diagnosis outcome variable of interest, intracranial injury, the top five principal diagnoses occurring in the sample were reported. Disposition (DISPUNIFORM), discharge quarter (DQTR) and length of stay (LOS) were analyzed unchanged.

DATA ANALYSIS

Data were analyzed using SAS, Release 9.2 (SAS Institute, Cary, NC, USA) and the PROC SURVEY methods to account for the complex survey design and minimize biased estimates or inaccurate variance calculations. National estimates were calculated by weighting the sample data using the DISCWT variable provided by AHRQ for such calculations. Continuous variables were analyzed using PROC SURVEYMEANS and categorical variables were analyzed using PROC SURVEYFREQ. Tests for associations were performed for continuous variables using the t-test for independent samples (PROC SURVEYREG) and categorical variables using the Rao-Scott x^2 test for proportions (PROC SURVEYFREQ). The t-test for independent samples tests the means of two separate populations being compared; similarly, the Rao-Scott x^2 test for proportions is a design-adjusted chi square that describes the differences in proportion estimates. Odds ratios were estimated to describe the strength of the relationship between the clinical outcomes of interest and motorcycle helmet use legislation. Multivariate analyses were conducted for intracranial injury (PROC SURVEYREG), in-hospital mortality (PROC SURVEYREG) and inpatient costs (PROC SURVEYLOGISTIC) to account for covariates identified in the literature and bivariate analyses; models were reduced through backward elimination until only covariates statistically significant remained. Statistical significance was established at $\alpha=0.05$ *a priori*.

Over the study period including years 2005, 2006 and 2007 of the HCUP NIS, there were 87,616 injury-related hospital discharges as a result of motorcycle-related crashes where nearly all (99.5%) were traffic-related (TABLE 2). The majority of motorcycle-related hospital discharges were male and aged 21-64 years, representing 87.9% and 83.1% of the sample population, respectively. The mean age of the population at admission was 37.8 years. Private insurance was the predominant expected primary payer (62.2%); no insurance (15.6%) was more than two times that of Medicaid (6.8%) and nearly four times that of Medicare (4%).

Most motorcycle-related hospitalizations came through the emergency department (84.9%), with fractures (49.1%) and intracranial injury (14.2%) the most frequent principal diagnoses (TABLE 3). The incidence of intracranial injury was 25.2%. The mean length of stay was 6.5 days and costs were $20,903. The majority of discharges were routine (72.2%), occurring most often in the third quarter (34.8%) and second quarter (30.1%) of the year, respectively.

Of all injury-related hospitalizations due to a motorcycle crash, more than half (n=44,490) occurred where universal motorcycle helmet use legislation was present (TABLE 4). Motorcyclists were significantly older where universal legislation was present than where it was absent, 38.7 years at admission versus 36.9 years ($p<0.0001$). In each group, males were predominant (44.4% and 43.6% where universal motorcycle helmet use legislation was present and absent, respectively,) as were motorcyclists aged 21-64 years (43.2% and 39.9%) and those with private insurance (33.4% and 30.6%).

The majority of injury-related hospitalizations due to motorcycle crashes were admitted through the emergency department in both groups (TABLE 5). In the absence of universal motorcycle helmet use legislation, intracranial injury and in-hospital mortality was 20% and nearly four times more likely to occur, respectively, than its presence (OR 1.20; 95% CI 1.022-1.418 and OR 3.825; 95% CI 3.061-4.781, respectively). Mean length of stay and costs associated with hospitalization were higher in the presence of universal legislation than where it was absent, 6.7 days and 6.2 days, respectively and $60,478 and $23,243, respectively ($p<0.0018$). Routine discharge was the most frequent discharge status in both groups, 37.5% and 34.8% where universal legislation was present and absent, respectively; discharge to a rehabilitation facility was higher where universal legislation was present, 2.1% (versus 1.3%) transferred to a short-term hospital and 6.3% (versus 6.2%) to a skilled nursing facility, intermediate care or other type of facility.

The results of the Rao-Scott x^2 tests for intracranial injury and in-hospital mortality and t-tests for independent samples for costs are provided in TABLE 6. The final multivariate logistic regression model for intracranial injury indicated that the adjusted odds of head injury was 17% higher in the absence of universal motorcycle helmet use legislation (OR 1.170; 95% CI 1.002-1.368) (TABLE 7). The final multivariate logistic regression model where in-hospital mortality was avoided suggested that the adjusted odds of survival in the presence of universal motorcycle helmet use legislation was more than twice that of when it was absent (OR 2.170; 95% CI 1.496-3.147) (TABLE 8). The final multivariate linear regression model for costs showed that costs were significantly higher where universal motorcycle helmet use legislation was present when all other covariates were held constant ($p<0.0394$) (TABLE 9).

The analysis presented compares the incidence of intracranial injury and in-hospital mortality as well as costs associated with motorcycle-related hospitalizations on the basis of universal motorcycle helmet use legislation in the US. To do so, all injury-related hospitalizations for motor vehicle accidents associated with a motorcycle within three years of the HCUP NIS were analyzed for differences and associations in clinical and economic outcomes between the presence and absence of universal motorcycle helmet use legislation.

The first null hypothesis is that there is no difference in intracranial injury rates on the basis of motorcycle helmet use legislation. Based on bivariate analysis, intracranial injuries are significantly higher in the absence of universal motorcycle helmet use legislation (p=0.0195; OR 1.20; 95% CI 1.022-1.418). Logit regression of the relationship between intracranial injury and universal motorcycle helmet use legislation demonstrated an estimated difference of 0.1577 and an adjusted odds ratio of OR 1.171 (95% CI 1.002-1.368) indicating that, in the absence of legislation, the odds of intracranial injury are significantly increased. As such, the author rejects the null hypothesis at the 5% level, indicating that the incidence of intracranial injury as a result of motorcycle-related crashes is different, i.e. higher, in the absence of universal motorcycle helmet use legislation.

The second null hypothesis is that there is no difference in in-hospital mortality rates on the basis of motorcycle helmet use legislation. Based on bivariate analysis, in-hospital mortality is significantly higher in the absence of universal motorcycle helmet use legislation (p<0.0001; OR 3.825; 95% CI 3.061-4.781). Logit regression of the relationship between in-hospital mortality and universal motorcycle helmet use legislation demonstrated an estimated difference of 0.7746 and an adjusted odds ratio of OR 2.170 (95% CI 1.496-3.147) indicating that the presence of such legislation, versus its absence, significantly increases the likelihood of survival. As such, the author rejects the null hypothesis at the 5% level, indicating that the incidence of in-hospital mortality as an outcome associated with motorcycle-related hospitalizations is different, i.e. higher, in the absence of universal motorcycle helmet use legislation.

The final null hypothesis is that there is no difference in inpatient costs on the basis of motorcycle helmet use legislation. Based on bivariate analysis, mean costs are significantly higher in the presence of universal motorcycle helmet use legislation (p=0.0018); probit regression of the relationship between costs and legislation confirmed the unadjusted results (p=0.0394). As such, the author rejects the null hypothesis at the 5% level, as costs are significantly higher when universal motorcycle helmet use legislation is in place.

There are several limitations to this analysis as a result of using the NIS HCUP dataset. The NIS HCUP dataset is limited to states that voluntarily provide data to AHRQ and subject to state-specific data restrictions and coding practices. Furthermore, general and specialty hospitals are included but long-term and psychiatric facilities are not a part of the dataset. Lastly, as the data collected by

AHRQ is primarily used for hospital billing, there is no clinical information included and some data may be missing or inconsistently reported.

Likewise, the delimitations of this analysis relate to the selection of the NIS HCUP data. Inpatient data is captured in the NIS dataset whereas data from other care settings, including emergency visits that did not result in an admission, are not captured. Additionally, the NIS data does not capture information regarding mortality at the scene of a motor vehicle crash or whether the motorcyclist was helmeted at the time of the crash; however, the intent of this analysis is to evaluate policy, i.e. universal motorcycle helmet use legislation, rather than individual outcomes and/or behavior. There is no way to account for cost avoidance due to the likelihood that helmeted motorcyclists are often not transported to the hospital nor incur rehabilitation costs as a result of significantly more intracranial injuries. Finally, the data is based on discharge information that may or may not be directly correlated to conditions present upon admission.

Data is widely available throughout the literature that demonstrates, as a result of universal motorcycle helmet use legislation, increased compliance with motorcycle helmet use, fewer adverse fatal and non-fatal outcomes and decreased healthcare resource utilization; as such, the analysis presented here provides additional support for the effectiveness of motorcycle helmet use legislation in injury prevention. Previous research evaluating costs associated with motorcycle helmet use have demonstrated significantly higher inpatient costs where motorcycle helmets are not used or mandatory universal use legislation is not in place. The higher costs found in this analysis where universal motorcycle helmet use legislation is present may be a result of increased mortality in the absence of such legislation, which would intuitively lead to a decrease in the length of stay and potentially lower inpatient costs. The costs reported as a result of this analysis are likely conservative as only those associated with the hospital stay are captured, thus the significant costs incurred before hospitalization or short- and long-term personal and societal costs are unaccounted for; when the value of a statistical life, $5 million, is considered, the cost effectiveness of motorcycle helmet use legislation exceeds billions of dollars (French, Gumus et al. 2009).

There are existing traffic safety policies aimed at injury prevention, e.g. automobile safety belts and child passenger safety seats, that demonstrate similar positive correlations between legislation and clinical and economic outcomes; however, the interest of public health in the case of motorcycle helmet use legislation has been significantly influenced by politics (Morrison, Petticrew et al. 2003; Jones and Bayer 2007; French, Gumus et al. 2009; Homer and French 2009). As there has been much debate and indecisive action based on data that demonstrates positive associations with universal motorcycle helmet use legislation, the likelihood that this analysis, which simply adds to the vast existing literature, will drive changes is low. Additional research and advocacy of other public health models and injury prevention strategies, such as mandatory driver and passenger safety education and training or substantially higher and meaningful insurance premiums to offset medical costs, to complement motorcycle helmet use legislation is warranted to increase the likelihood that Congress may uphold any future legislation that encourages state adoption of universal motorcycle helmet use legislation as persuasion of state legislatures to maintain or re-enact such legislation based on fact alone has, to-date, proven futile (Mayhew and Simpson 2002; Morrison, Petticrew et al. 2003; Derrick and Faucher 2009).

Table 1. Medical Subject Headings (MeSH) Classification and Terms

Classification	Terms
Major Topic	Motorcycle
	Traffic Accident
	Hospital Costs
Subheading	Analysis
	Economics
	Epidemiology
	Legislation and Jurisprudence
	Mortality
	Prevention and Control
	Statistics and Numerical Data

Table 2. Study Population Demographics

Injury-Related Hospital Discharges as a Result of Motorcycle Crashes (N=87,616)	
Demographics	n [SD] (%)
Motorcycle Helmet Use Legislation	
Partial/No	43,126 [3,882] (49.2)
Universal	44,490 [3,517] (50.8)
Event location	
Traffic	84,740 [4,513] (99.5)
Non-traffic	400.1 [47.8] (0.5)
Gender of patient	
Male	76,185 [4,098] (87.9)
Female	10,444 [616] (12.1)
Age at admission, mean [SD]	37.8 [0.3]
Age group at admission	
Pediatric (aged ≤ 20 years)	11,797 [576.6] (13.5)
Adult (aged 21-64 years)	72,806 [4,052] (83.1)
Elderly (aged≥ 65 years)	3,013 [190.6] (3.4)
Expected primary payer	
Medicare	3,497 [207.8] (4)
Medicaid	5,940 [528] (6.8)
Private, including HMO	54,343 [3,179] (62.2)
Self-pay	13,647 [985.4] (15.6)
No charge	1,171 [396.1] (1.3)
Other	6,267 [602.9] (7.2)
Median income for patient’s zip code	
$1-$35,999	19,229 [1,476] (23.3)
$36,000-$44,999	21,205 [1,337] (25.7)
$45,000-$58,999	22,631 [1,442] (27.4)
$59,000 or more	19,538 [1,301] (23.7)

Table 3. Study Population Clinical Characteristics

Injury-Related Hospital Discharges as a Result of Motorcycle Crashes (N=87,616)	
Characteristics	n/mean [SD] (%)
Admission source	
Emergency department	68,736 [4,123] (84.1)
Another hospital	2,696 [321.8] (3.3)
Another facility	606.3 [129.2] (0.7)
Court/law enforcement	14.3 [8.3] (0.0)
Routine/other	9,726 [803.3] (11.9)
Admission type	
Emergency	50,536 [3,581] (70.8)
Urgent	6,687 [628.5] (9.4)
Elective	4,230 [306] (5.9)
Trauma Center	9,753 [1,770] (13.7)
Other	137.2 [74.8] (0.2)
Intracranial injury	22,051 [1,668] (25.2)
Top 5 principal diagnoses	
Fractures	9,743 (49.1)
Intracranial injury	2,824 (14.2)
Crushing injury or internal injury	2,046 (10.3)
Open wounds	860 (4.3)
Superficial injury; contusion	332 (1.7)
Length of stay	6.5 (0.2)
Costs	20,903 (727.1)
Discharge status	
Routine	61,463 [3,130] (72.2)
Transfer to short-term hospital	2,895 [273.4] (3.4)
Other transfers	10,596 [862] (12.5)
Home health care	7,149 [523.7] (8.4)
Against medical advice	678.3 [74.3] (0.8)
Died in hospital	2,238 [208.5] (2.6)
Discharged alive, destination unknown	96.7 [56.5] (0.1)
Discharge quarter	
January-March	10,353 [833.8] (11.8)
April-June	26,917 [1,525] (30.1)
July-September	30,470 [1,642] (34.8)
October-December	17,400 [1,054] (19.9)

Table 4. Demographics According to Motorcycle Helmet Use Legislation

Injury-Related Hospital Discharges as a Result of Motorcycle Crashes (N=87,616)		
Demographics	Partial/No Legislation (n=43,126)	Universal Legislation (n=44,490)
Gender of patient, n [SD] (%)		
Male	37,751 [3,415] (43.6)	38,434 [3,068] (44.4)
Female	5,370 [506] (6.2)	5,074 [453.4] (5.9)
Age at admission, mean [SD][a]	36.9 [0.3]	38.7 [0.3]
Age group at admission, n [SD] (%)[b]		
Pediatric (aged ≤ 20 years)	6,740 [472.8] (7.7)	5,057 [426] (5.8)
Adult (aged 21-64 years)	34,954 [3,371] (39.9)	37,851 [3,031] (43.2)
Elderly (aged≥ 65 years)	1,431 [147.6] (1.6)	1,582 [140] (1.8)
Primary payer, expected, n [SD] (%)[b]		
Medicare	1,640 [146.1] (1.9)	1,857 [165.4] (2.2)
Medicaid	2,461 [339.5] (2.9)	3,479 [438.7] (4.1)
Private, including HMO	26,002 [2,592] (30.6)	28,340 [2,284] (33.4)
Self-pay	6,729 [761.4] (7.9)	6,919 [728] (8.2)
No charge	951.6 [387.2] (1.1)	219.3 [81.3] (0.3)
Other	2,798 [430.4] (3.3)	3,468 [464.1] (4.1)
Median income for patient's zip code, n [SD] (%)[b]		
$1-$35,999	9,942 [1,142] (12)	9,288 [1,107] (11.2)
$36,000-$44,999	10,863 [1,025] (13.2)	10,342 [1,024] (12.5)
$45,000-$58,999	11,229 [1,232] (13.6)	11,402 [943.1] (13.8)
$59,000 or more	7,351 [824.1] (8.9)	12,186 [1,099] (14.8)

[a] t-test, $p < 0.05$. [b] Rao-Scott x^2 test, $p < 0.05$.

Table 5. Clinical Characteristics According to Motorcycle Helmet Use Legislation

Injury-Related Hospital Discharges as a Result of Motorcycle Crashes (N=87,616)		
Characteristics	Partial/No Legislation (n=43,126)	Universal Legislation (n=44,490)
Admission source, n [SD] (%)[b]		
Emergency department	33,647 [3,399] (41.2)	35,089 [2,911] (42.9)
Another hospital	1,211 [229.2] (1.5)	1,485 [234] (1.8)
Another facility	225.2 [62] (0.3)	381.1 [114.1] (0.5)
Court/law enforcement[+]	-	-
Routine/other	3,909 [426.7] (4.8)	5,816 [717.1] (7.1)
Admission type, n [SD] (%)[b]		
Emergency	25,966 [2,727] (36.4)	24,570 [2,729] (34.4)
Urgent	3,738 [356.1] (5.2)	2,949 [528.7] (4.1)
Elective	2,286 [260.8] (3.2)	1,945 [179.2] (2.7)
Trauma Center	7,455 [1,617[(10.5)	2,298 [751.4] (3.2)
Other	132.8 [74.5] (0.2)	*
Intracranial injury, n [SD] (%)[b,c]	11,619 [1,464] (13.3)	10,432 [1,066] (11.9)
Top 5 principal diagnoses, %		
	Fracture (fx) 41.8	Fracture (fx) 57.8
	Lower limb fx 20.3	Lower limb fx 28.4
	Intracranial 14.6	Intracranial 13.9
	Other intracranial 11.8	Upper limb fx 13.1
	Tibia/fibula fx 9.1	Tibia/fibula fx 12.6
In-hospital mortality, n [SD] (%)[b,d]	3,680 [172.1] (4.2)	1,059 [152.5] (1.2)
Length of stay, mean days [SD]	6.2 [0.3]	6.7 [0.2]
Costs, mean dollars [SD][a]	18,483 [1,083.8]	23,243 [1059.8]
Discharge status, n [SD] (%)[b]		
Routine	29,564 [2,666] (34.8)	31,899 [2,414] (37.5)
Transfer to short-term hospital	1,095 [116.7] (1.3)	1,799 [252.8] (2.1)
Other transfers	5,275 [730.8] (6.2)	5,321 [569.4] (6.3)
Home health care	3,171 [396.5] (3.7)	3,978 [407.7] (4.7)
Against medical advice	341.7 [54.7] (0.4)	336.5 [52.6] (0.4)
Died in hospital	1,185 [166.7] (1.4)	1,054 [151.3] (1.2)
Discharged alive, destination unknown[+]	-	-
Discharge quarter, n [SD] (%)		
January-March	5,105 [756.3] (7.5)	5,249 [475.5] (7.8)
April-June	12,786 [1,197] (18.9)	14,131 [1,169] (20.9)
July-September	14,305 [1,270] (21.1)	16,165 [1,272] (23.9)
October-December[+]	-	-

[a] t-test, $p < 0.05$. [b] Rao-Scott x^2 test, $p < 0.05$. [c] OR 1.204; CI 1.022-1.418. [d] OR 3.825; CI 3.061-4.781
* suppressed statistics based on ≤10 weighted observations. [+] statistics unavailable due to zero cell frequency.

Table 6. Tests of Association for Intracranial Injury, In-hospital Mortality and Costs

Variable	Intracranial Injury	In-hospital Mortality	Costs
Age at admission	<0.0001	<0.0001	<0.0001
Age group at admission	<0.0001	<0.0001	<0.0001
Admission source	<0.0001	0.1707	0.0177
Admission type	<0.0001	<0.0001	<0.0001
Costs	<0.0001	0.0010	n/a
Discharge status	<0.0001	n/a	<0.0001
Discharge quarter	0.5538	0.9489	<0.0001
Gender	0.0154	<0.0001	0.0140
In-hospital mortality	<0.0001	n/a	0.001
Intracranial injury	n/a	<0.0001	<0.0001
Legislation	0.0195	<0.0001	0.0018
Length of stay	<0.0001	<0.0001	<0.0001
Median income for patient's zip code	0.8286	0.8239	<0.0001
Primary payer, expected	0.7457	0.0213	0.0009

Table 7. Final Regression Model Parameters for Intracranial Injury

Parameter	Coefficient	Pr > ChiSq	Odds Ratio	Odds Ratio 95% CI	
Intercept	0.3237	0.2879			
Legislation	0.1577	0.0469	1.171	1.002	1.368
Age at admission	-0.00341	0.0223	0.997	0.997	1.000
Admission source	-0.1823	<0.0001	0.833	0.787	0.883
Admission type	0.1163	<0.0001	1.123	1.072	1.177
Costs	5.722×10^{-3}	0.0057	1.000	1.000	1.000
Disposition of patient	0.0374	0.0038	1.038	1.012	1.065
In-hospital mortality	-1.6623	<0.0001	0.190	0.109	0.331
Length of stay	0.0187	0.0013	1.019	1.007	1.031

Table 8. Final Regression Model Parameters for In-hospital Mortality

Parameter	Coefficient	Pr > ChiSq	Odds Ratio	Odds Ratio 95% CI	
Intercept	-1.6843	<0.0001			
Legislation	0.7746	<0.0001	2.170	1.496	3.147
Age at admission	0.0309	<0.0001	1.031	1.025	1.038
Admission type	0.2204	0.0038	1.247	1.074	1.447
Costs	-0.00007	0.0001	1.000	1.000	1.000
Gender	0.7012	0.0003	2.016	1.384	2.936
Intracranial injury	-1.8242	<0.0001	0.161	0.128	0.203
Length of stay	0.4153	<0.0001	1.515	1.246	1.841
Primary payer, expected	1.1991	<0.0001	3.317	2.907	3.785

Table 9. Final Regression Model Parameters for Costs

	R^2 0.7277	
Parameter	Coefficient	Pr > t
Intercept	532.56112	0.6027
Legislation	1539.06408	0.0394
Age	-65.80042	<0.0001
Admission source	-779.98174	<0.0001
Admission type	956.77477	0.0062
Discharge status	887.28885	<0.0001
Intracranial injury	1527.788891	0.0011
Length of stay	2475.17262	<0.0001
Median income for patient's zip code	804.89738	0.0004

APPENDIX 1. EXTERNAL CAUSES OF INJURY AND POISONING CODES (ECODES) FOR MOTORCYCLE-RELATED CRASHES

Motor Vehicle Traffic Accidents(E810-E819)
The fourth-digit subdivisions are to identify the injured person as the
- 2 Motorcyclist
- 3 Passenger on motorcycle

E810 Motor vehicle traffic accident involving collision with train
E811 Motor vehicle traffic accident involving re-entrant collision with another motor vehicle
E812 Other motor vehicle traffic accident involving collision with motor vehicle
E813 Motor vehicle traffic accident involving collision with other vehicle
E814 Motor vehicle traffic accident involving collision with pedestrian
E815 Other motor vehicle traffic accident involving collision on the highway
E816 Motor vehicle traffic accident due to loss of control, without collision on the highway
E817 Noncollision motor vehicle traffic accident while boarding or alighting
E818 Other noncollision motor vehicle traffic accident
E819 Motor vehicle traffic accident of unspecified nature

Motor Vehicle Nontraffic Accidents (E820-E825)
The fourth-digit subdivisions are to identify the injured person as the
- 2 Motorcyclist
- 3 Passenger on motorcycle

E820 Nontraffic accident involving motor-driven snow vehicle
E821 Nontraffic accident involving other off-road motor vehicle
E822 Other motor vehicle nontraffic accident involving collision with moving object
E823 Other motor vehicle nontraffic accident involving collision with stationary object
E824 Other motor vehicle nontraffic accident while boarding and alighting
E825 Other motor vehicle nontraffic accident of other and unspecified nature

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