ORIGINAL ARTICLE

Impact of North Carolina's Motorcycle Helmet Law on Hospital Admissions and Charges for Care of Traumatic Brain Injuries

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BACKGROUND North Carolina requires motorcyclists of all ages to wear federally approved safety helmets. The purpose of this article is to estimate the impact of this state law in terms of hospital admissions for traumatic brain injury (TBI) and associated hospital charges.

METHODS Hospital admissions of North Carolina motorcyclists with TBIs and associated hospital charges in 2011 were extracted from the North Carolina Hospital Discharge Data system. We estimated hospital admissions and charges for the same year under the counterfactual condition of North Carolina without a universal motorcycle helmet law by using various substitutes (Florida, Pennsylvania, and South Carolina residents treated in North Carolina).

RESULTS North Carolina's universal helmet law prevented an estimated 190 to 226 hospital admissions of North Carolina motorcyclists with TBI in 2011. Averted hospital charges to taxpayer-funded sources (ie, government and public charges) were estimated to be between $9.5 million and $11.6 million for 2011, and total averted hospital charges for 2011 were estimated to be between $25.3 million and $31.0 million.

LIMITATIONS Cost estimates are limited to inpatients during the initial period of hospital care. This study was unable to capture long-term health care costs and productivity losses incurred by North Carolina's TBI patients and their caregivers.

CONCLUSIONS North Carolina's universal motorcycle helmet law generates health and economic benefits for the state and its taxpayers.

Motorcycling is a popular and fuel-efficient means of commuter transportation, and it provides a social focus for communities of recreational motorcyclists. From a traffic safety perspective, however, motorcyclists are a high-risk population of road users. Relative to passenger car occupants, motorcyclists are more than 26 times as likely to be killed and 5 times as likely to be nonfatally injured, per vehicle mile traveled [1]. A variety of factors contribute to this disparity. Motorcycles are less conspicuous than passenger vehicles [2, 3] and are thus more likely to be involved in traffic crashes; motorcycles provide less protection from crash forces because of their open design; and motorcyclists are over-represented in alcohol-related and speed-related fatal crashes [1].

Traumatic brain injuries (TBIs) are a leading cause of motorcycle-related deaths and are among the most severe and costly nonfatal motorcyclist injuries [4, 5]. Nonfatal TBIs consume significant medical resources in the acute phase of treatment, and patients with nonfatal TBIs may also require extensive rehabilitation [4]. Helmets that meet federal safety standards are the most effective way to reduce the risk of head trauma in a motorcycle crash [6]. Helmets are estimated to be 42% effective at preventing death and 69% effective at preventing head injury when a crash occurs [7].

Universal helmet laws, defined as laws that require all motorcycle riders to wear a helmet, are effective for sustaining high levels of helmet use [8, 9]. Currently, 19 states and the District of Columbia have universal helmet laws [10]. Among the remainder of states, 3 states have no helmet law, and 28 states have partial helmet laws. Partial helmet laws require only certain subgroups of motorcycle riders to wear a helmet, usually those under the age of 18 or 21 years. Multiple studies have reported that when states repeal a universal helmet law or weaken their universal helmet law to a partial helmet law, helmet use decreases and motorcycle-related deaths and head injuries increase [9, 11-14].

The purpose of this study was to estimate the impact of North Carolina's universal motorcycle helmet law on the incidence and burden of motorcycle-related TBIs to North Carolina residents. North Carolina has high levels of helmet use, and the state's motorcycle injury and death rates are below those of Southeastern states without universal helmet laws, such as South Carolina and Florida [15-17]. However, an analysis of the impact of North Carolina's universal helmet law has not previously been conducted. This study focused on hospital admissions and charges for the initial period of care for North Carolina motorcyclists with TBIs who were treated as inpatients in the state's hospitals.

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Methods

This study examined hospital charges for North Carolina residents admitted to the state's hospitals in calendar year 2011 (January 1, 2011 to December 31, 2011). We quantified the health care impact of the state's universal helmet law by comparing the observed (actual) incidence and charges for these patients with those of a hypothetical (counterfactual) scenario in which North Carolina had no universal helmet law in 2011. The counterfactual concept is used to compare health outcomes in a given population under 2 different scenarios. For example, one could compare disease incidence in an exposed population to the incidence in the same population in an unexposed condition [18]. Clearly, 1 of these 2 scenarios is hypothetical and therefore unobservable [18]. The unobservable scenario is called the "counterfactual condition," as it is counter-to-fact (or counter-to-reality) [18]. For this study, our "exposure" was North Carolina's universal motorcycle helmet law, and our "exposed" scenario was the actual and observable hospital charges. To estimate hospital charges in the "unexposed" counterfactual condition (ie, North Carolina without a universal helmet law), we used discharge data from North Carolina hospitals combined with results from published evaluations from other states that have weakened or repealed helmet laws [9, 12, 13].

Actual Inpatient Incidence and Hospital Charges for 2011

Data on motor vehicle traffic-related injuries sustained by North Carolina motorcyclists admitted to the state's hospitals in 2011 were abstracted from the North Carolina Hospital Discharge Data (HDD) system. HDD are abstracted from hospital administrative claim forms used to bill payers. Hospitalized motorcyclists were identified using International Classification, 9th Revision, Clinical Modification (ICD-9-CM) external cause of injury codes (E-codes) in the range E810–E819 with a fourth digit of .2 or .3. Among these discharge records, motorcyclists suffering a TBI were identified using ICD-9-CM diagnosis codes 800.0–810.9, 803.0–804.9, 850–854.19, 950.1–950.3, 959.01, or 995.55; these codes are consistent with the definition of TBI proposed by the Centers for Disease Control and Prevention (CDC). Total hospital charges included those incurred during the initial period of care that were related to intensive care unit/critical care unit care, surgery, laboratory, pharmacy, radiology, respiratory, therapy, and supplies, as well as routine charges. Hospital charges from the HDD system represent the charges that would be billed to someone without insurance; for this study, we included only those charges billed to a patient for an initial hospitalization associated with the treatment of a motorcycle crash–related TBI. These charges are not equivalent to actual costs. The average charge-to-cost ratio for North Carolina hospitals was approximately 3.2:1 in the period 2011–2012 [19]. However, we do not present costs here, because charge-to-cost ratios are an approximation and can vary considerably by hospital.

Counterfactual Inpatient Incidence and Hospital Charges

The counterfactual scenario of interest is the hypothetical condition in which North Carolina had no universal helmet law in 2011. In states where a universal helmet law has been repealed or weakened to a partial helmet law, there are generally 2 TBI-related effects: an increase in the number of motorcyclists with TBIs, and an increase in the average cost of care per motorcyclist with a TBI [12, 13]. Our analyses therefore estimated both an increase in the incidence of TBIs and an increase in average costs. We estimated these parameters using data from other states. Because there is uncertainty in utilizing data from other states as a substitute for the counterfactual North Carolina, we used 3 different populations to estimate the increases in TBI incidence and average cost of care: pre-repeal and post-repeal data from Florida [13]; pre-repeal and post-repeal data from Pennsylvania [12]; and results of universal helmet law repeal impacts from the Community Preventive Services Task Force [9] combined with data on hospital charges for South Carolina residents treated for motorcycle crash–related TBIs in North Carolina hospitals. We present a range of estimates based on these 3 populations.

Florida and Pennsylvania were selected because these states are approximately comparable to North Carolina in terms of factors that influence motorcyclist behaviors and exposures (eg length of riding season and road environment) and because well-conducted evaluation studies of universal helmet law repeal were available for these states. South Carolina residents treated in North Carolina hospitals were selected because they provided a comparison group treated in the same hospitals as North Carolina residents. Like the data on North Carolina residents, data on these patients were obtained from North Carolina's HDD system.

In the Florida study, Ulmer and Northrup [13] examined acute care hospital-admitted motorcyclists with a principal diagnosis of head, brain, or skull injury before and after the January 2000 repeal of Florida's universal helmet law. Comparing the 30 months pre-law to the 30 months post-law, they found cases increased from 602 to 1,097, for an increase of 82% [13]. Adjusted for inflation, the total cost of acute care for these injuries averaged $34,518 per case in the 30 months pre-law and $39,877 per case in the 30 months after the law change, for an increase of 16% [13].

In the Pennsylvania study, Mertz and Weiss [12] examined motorcycle-related hospitalizations with head injuries (having a TBI code listed as one of the first 5 ICD-9-CM diagnosis codes, with TBI defined based on the CDC definition). The authors examined hospitalizations 2 years before (2001–2002) and 2 years after (2004–2005) the September 2003 repeal of Pennsylvania's universal helmet law. They found that motorcycle-related head injury hospitalizations increased 78% during this time [12], and the percentage increase in the mean charge per motorcycle-related head injury hospitalization was 32% [12].

Motorcyclists who were residents of South Carolina,

a state without a universal helmet law, who were treated in North Carolina hospitals provided a third estimate of expected average hospital charges in the counterfactual condition. For some areas of South Carolina, the nearest trauma hospital is located in North Carolina. We assumed that many of the South Carolina motorcyclists treated in North Carolina hospitals were involved in crashes in South Carolina near the border of the 2 states; we also assumed that the helmet use and distribution of TBI severity among these South Carolina residents were representative of all South Carolina residents admitted to hospitals with TBIs in 2011. The average charge for South Carolina inpatients with motorcycle-related TBIs was extracted from the North Carolina HDD system. The criteria used to define motorcycle-related TBIs for South Carolina patients were identical to those used for North Carolina patients. South Carolina patients had a mean charge per case of $104,814, compared to $83,428 for North Carolina residents, for an increase of 26%.

Because the North Carolina HDD system could not be used to estimate the expected increase in hospital admissions for North Carolina motorcyclists with TBIs under the counterfactual condition, we used an estimate from a recent systematic review from the Community Preventive Services Task Force [9]. This review estimated a 69% increase in nonfatal head injuries when a state changes from a universal helmet law to a partial helmet law or no helmet law [9].

Calculations of Counterfactual Inpatient Admissions, Total Charges, and Charges by Payer Source

To calculate the expected number of hospital admissions for North Carolina motorcyclists with TBIs under the counterfactual condition, we multiplied the actual number of motorcycle-related TBI admissions in North Carolina in 2011 by the expected incidence increase for each of the 3 substitute populations (FL, 82%; PA, 78%; SC, 69%). To estimate the expected mean charge per motorcycle-related TBI admission for the counterfactual condition, we multiplied the actual average charge per motorcycle-related TBI admission by the expected average charge increase in each of the 3 substitute populations (FL, 16%; PA, 32%; SC, 26%). Finally, to estimate total hospital charges, the expected mean charge per admitted motorcyclist was multiplied by the expected number of admitted motorcyclists. Annual averted hospital charges were calculated as the difference between the actual charges in 2011 and the estimated charges obtained from each of the 3 substitute populations discussed above.

To estimate expected charges billed to each source of payment, we obtained data on expected sources of payment for hospitalized motorcyclists with TBIs from 2011 North Carolina HDD claims. Expected sources of payment were categorized as government or other public sources, such as Medicaid and Medicare (hereafter referred to as "taxpayer sources"); private insurance (eg, Blue Cross and Blue Shield of North Carolina) and other forms of payment; and self-payment. To estimate the total expected charges for each source of payment, the percentage of all charges billed to each source of payment was multiplied by the total expected charges.

Results

In 2011, there were 275 hospital admissions of North Carolina motorcyclists with TBIs (See Table 1). The mean hospital charge per case was approximately $83,400; the total charge for all cases was $22.9 million.

If North Carolina's universal helmet law had been weakened or repealed in 2011 (counterfactual condition), the expected number of hospital admissions for North Carolina motorcyclists with TBIs would have increased to between 465 and 501 cases. This range is the actual number of motorcycle-related TBI admissions (n=275), multiplied by the expected incidence increase for each of the 3 substitute populations (FL, 82%; PA, 78%; SC, 69%).

Additionally, the expected mean charges per North Carolina motorcyclist with a TBI would have increased to between $96,400 and $110,100. This range is the actual average charge per motorcycle-related TBI admission ($83,428) multiplied by the expected average charge increase in each of the 3 substitute populations (FL, 16%; PA, 32%; SC, 26%).

Combining expected incidences and expected mean charges per North Carolina motorcyclist with a TBI yielded total expected charges of $48.3 million to $53.9 million in the counterfactual condition, more than double the actual charges. Thus, by maintaining a universal helmet law in 2011, between $25.3 million and $31.0 million in hospital charges were averted (expected charges minus actual charges).

Charges to taxpayer sources for the treatment of North Carolina motorcyclists in the state's hospitals were approximately $8.6 million in 2011, or 38% of total charges (See Table 1). Applying this proportion to total expected charges if North Carolina's universal helmet law had been weakened or repealed in 2011 (counterfactual condition), we found that expected hospital charges to taxpayer sources would have increased to between $18.2 million and $20.3 million. Therefore, maintaining a universal helmet law averted between $9.5 million and $11.6 million in hospital charges to taxpayer sources. Averted charges for private sources were $12.6 million to $15.4 million, and averted charged for self-payment were $3.2 million to $3.9 million.

Discussion

Universal helmet laws increase helmet use, prevent injuries and deaths, and reduce costs [9, 20-25]. Similarly, weakening or repealing these laws has been shown to decrease helmet use, increase injuries and deaths, and increase costs [9, 11-14]. By maintaining North Carolina's universal helmet law, there were between 190 and 226 fewer hospital admissions of North Carolina motorcyclists with TBIs in 2011 than if the state had not had a universal helmet law. Additionally,

TABLE 1.
Actual and Projected Incidence and Hospital Inpatient Charges[a] for Motorcyclists With Traumatic Brain Injury (TBI), North Carolina, 2011

	Source or substitute population	Annual number of motorcyclist TBI hospital admissions	Average hospital charge per motorcyclist TBI inpatient admission	Hospital inpatient charges for motorcyclist TBIs			
				Government and public sources	Private sources and other payments	Self-payment	Total charges (all sources)
Universal motorcycle helmet law in effect (actual)	North Carolina 2011	275	$83,428	$8,624,989	$11,430,761	$2,886,961	$22,942,711
No universal motorcycle helmet law (counterfactual)	Florida 2000[b]	501	$96,359	$18,150,504	$24,054,996	$6,075,347	$48,280,847
	Pennsylvania 2003[c]	490	$110,125	$20,265,264	$26,857,703	$6,783,201	$53,906,168
	South Carolina residents treated in North Carolina hospitals 2011[d]	465	$104,814	$18,312,705	$24,269,962	$6,129,639	$48,712,307
Averted losses (counterfactual minus actual)	Florida 2000[b]	226	$12,931	$9,525,515	$12,624,235	$3,188,386	$25,338,136
	Pennsylvania 2003[c]	215	$26,697	$11,640,275	$15,426,942	$3,896,240	$30,963,457
	South Carolina residents treated in North Carolina hospitals 2011[d]	190	$21,386	$9,687,716	$12,839,201	$3,242,678	$25,769,596

[a]Hospital inpatient charges for initial period of care, 2011 dollars, for North Carolina residents only.

[b]Ulmer and Northrup [13] reported an 82% increase in incidence and a 16% increase in mean cost following the weakening of Florida's motorcycle helmet law from a universal to a partial law.

[c]Mertz and Weiss [12] reported a 78% increase in incidence and a 32% increase in mean charges following the weakening of Pennsylvania's motorcycle helmet law from a universal to a partial law.

[d]South Carolina residents with motorcycle crash–related TBI treated in North Carolina hospitals in 2011 had mean charges that were 26% higher than North Carolina residents with motorcycle crash–related TBI. This estimate assumes a 69% increase in incidence based on pooled data from other states [9].

we estimated that total hospital charges for admitted North Carolina motorcyclists with TBIs were approximately half what they would have been without a universal helmet law. Our estimates of averted charges by payer source indicated that approximately $9.5 million to $11.6 million in hospital charges to taxpayer-based payer sources were averted. However, the proportion of averted charges to taxpayer-based payer sources may be an underestimate. Lawrence and colleagues [26] noted that some motorcyclists designated as "self-pay" on billing records may have some proportion of their costs shifted to government sources if they become unable to pay all of their bills due to the costly nature of their injuries.

It is important to note that this study was focused on the initial period of care only. Initial care is typically only a small proportion of the care provided (and total costs incurred) during the treatment and recovery from TBI. The CDC reported that lifetime medical costs associated with nonfatal hospitalized TBIs averaged about $79,000 per patient in 2010 dollars, and lifetime work loss costs averaged an additional $179,000 per patient [16]. Additionally, Whiteneck and coauthors [27] found that about one-third of adults hospitalized with TBI from all causes still required help with daily activities 1 year after their discharge. Miller and colleagues [28] documented major employment impacts for motorcyclists with TBIs; specifically, employment levels dropped from just over 80% to 45% by 1 year post-injury, and unemployment tripled (11% to 32%). In addition to personal productivity losses, there are significant losses associated with caregiver burden and reduced quality of life [4, 26].

The results of this study confirm a previous study reporting that universal helmet laws produce economic benefits [29]. The previous study reported that states with universal helmet laws save, on average, nearly 4 times the costs per registered motorcycle compared to states without a universal helmet law. Moreover, that study found that North Carolina led the nation in terms of both lives saved and costs saved by helmet use per registered motorcycle. Helmet use in North Carolina was estimated to save $163 million in medical and productivity costs per 100,000 registered motorcycles in 2010. For comparison, Southeastern states without universal helmet laws, such as South Carolina and Florida, were estimated to save $27 million and $38 million per 100,000 registered motorcycles, respectively [6, 29].

Some states that have weakened a universal helmet law to a partial helmet law have attempted to address the costly nature of motorcycle injuries by requiring that unhelmeted motorcyclists carry a minimal amount of insurance to cover the medical costs associated with a potential crash [10]. However, research has shown that these legislative provisions are typically insufficient to cover the increased costs

associated with motorcycle crash injuries, and many of the costs are paid by taxpayer-funded sources [13]. Florida weakened its motorcycle helmet law from a universal helmet law to a partial helmet law; the latter required helmet use only by riders under the age of 21 years and those with less than $10,000 of medical insurance. However, after the change in the law, less than a quarter of hospitalized motorcyclists with TBIs had medical costs that were less than $10,000; indeed, the mean cost per case was nearly $40,000 (in 1998 dollars) [13]. Additionally, only 63% of those admitted with head injuries were covered by private insurance; the remainder had their treatment classified as self-pay, or their care was billed to charitable or public sources [13].

This study has some limitations. First, we relied on E-codes to identify hospitalized motorcyclists with a TBI. While North Carolina hospitals have high use of E-codes, it is possible that some motorcyclists with TBIs were not correctly coded as such [30]. Therefore, our results could underestimate the true number of injured motorcyclists. Second, we presented a range of estimated injury incidences and mean charge increases, and each estimate was based on a slightly different injury definition. The Pennsylvania estimate used a similar definition to that used in our study by including motorcyclists with a TBI code as 1 of the first 5 ICD-9-CM diagnosis codes [12]. The Florida estimate included hospital-admitted motorcyclists with a principal diagnosis of a head, brain, or skull injury [13], which is identical to the definition used in our study. While our estimate based on South Carolina residents admitted to North Carolina hospitals used the same injury definition, we assumed that the distribution of TBI severity for these South Carolina residents was representative of what the TBI severity distribution for North Carolina residents would have been had the state lacked a universal helmet law. This may not be the case if more severe injuries are associated with an increased probability of transfer across state lines. Third, because we do not have information on North Carolina motorcyclists admitted to out-of-state hospitals, total charges associated with hospital admissions for North Carolina motorcyclists with TBIs are likely greater than what we have presented here. Fourth, some of the discharges included here result from transfers between hospitals or readmissions, but this is expected to be a small proportion of the overall number of total discharges. Finally, it is important to note that charges are not equivalent to actual costs.

Conclusion

North Carolina's universal motorcycle helmet law provides key benefits in terms of reduced TBI hospital admissions of North Carolina motorcyclists and averted hospital charges. North Carolina hospitals had approximately 190 to 226 fewer admissions for North Carolina motorcyclists with TBIs in 2011 than would have been expected in the absence of a universal helmet law. Total charges for the initial, acute care of North Carolina motorcyclists hospitalized with TBIs were approximately half what they would have been without a universal helmet law. The state's universal helmet law thus averted between $9.5 million and $11.6 million in hospital charges to taxpayer-based payer sources.

While this study focused on hospital charges associated with initial treatment, the total economic burden associated with motorcycle crash–related TBIs is far greater. The total cost of such injuries involves recurrent costs of therapy, loss of earnings capacity, and disability replacement costs. This study did not include data on these costs. NCMJ

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