The Medical and Economic Impact of Motorized Recreational Vehicle-Related Traumatic Brain Injury in Ohio

The Ohio CODES Program
Center for Injury Research and Policy
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Introduction

This study extends the current research at the Center for Injury Research and Policy (CIRP) on motorized recreational vehicle (MRV)-related injuries by investigating the medical and economic impact of MVR-related traumatic brain injury (TBI) in Ohio. Our *long-term goal* is to prevent TBI -related morbidity and mortality in Ohio, especially related to use of MRVs. The *objective* of this study was to describe the medical and economic impact of these injuries in Ohio, and identify key factors that are associated with the outcome of individuals who sustain moderate to severe TBI. This information will ultimately contribute to the development of informed public policy and evidence-based, targeted educational efforts.

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Executive Summary

Statement of Problem - MRVs, and especially All-Terrain Vehicles (ATV), cause many injuries and deaths in Ohio[1,2] and nationally. TBI is the most serious type of MRV-associated injury and often results in death or life-long severe disability. Despite its importance, the medical and economic impact of traumatic brain injury, and in particular, MRV-related TBI, has not been investigated in Ohio.

Study Objective - This study describes the medical and economic impact of traumatic brain injuries in Ohio, and identifies key factors that are associated with the outcome of individuals who sustain moderate to severe TBI. Our *central hypothesis* was that there are identifiable risk factors (such as operator age) and protective factors (such as the use of a helmet) that are associated with the outcome (hospital charges, injury severity, and survival) of individuals with MRV-related TBI. Determining the key factors associated with MRV-related TBI outcome will facilitate development of informed public policy and evidence-based, targeted educational efforts in Ohio to prevent these injuries. We tested our central hypothesis by achieving the following specific, measurable, and time-framed objectives, which represent our *specific aims*. *Specific Aim 1:* Describe the medical and economic impact of traumatic brain injury, including motorized recreational vehicle-related traumatic brain injury, in Ohio. *Specific Aim 2:* Test the hypothesis that there are identifiable risk factors (i.e., age, alcohol involvement) and protective factors (i.e., use of a helmet) that are associated with the outcome (hospital charges, injury severity, and survival) of individuals with motorized recreational vehicle-related traumatic brain injury.

Methodology - We conducted an investigation of this problem using probabilistically-linked statewide datasets (Crash Information System, Emergency Medical Services Incidence Reporting System, Ohio Trauma Registry, and Emergency Department and In-patient Hospital Database for the years 2003-2006). These databases were linked using sophisticated probabilistic linkage software. Our analysis involved linked data from the Ohio Trauma Registry and Emergency Department and In-patient Hospital Database, as these datasets provided information most pertinent to our specific aims.

Major Conclusions - Motor vehicle crashes and falls account for the majority (65%) of TBI cases in Ohio, while MRVs are associated with slightly less than 5% of TBIs statewide. The average annual hospital charges in Ohio for TBI and MRV-related TBI are approximately $241,081,000 and $10,461,000, respectively. TBI occurs to individuals of all ages; however, among trauma patients, younger individuals are more likely to sustain a TBI than older individuals. This is especially the case for MRV-related TBI. Hospital charges are greater for TBIs than non-TBIs. Substance use and protective safety equipment use are associated with TBI outcome. Alcohol use increases the likelihood of a TBI among injured MRV riders. Helmet use reduces the likelihood of a TBI among injured MRV users. We recommend a combination of education and legislative action to decrease the morbidity and mortality due to MRV-related TBI in Ohio.

Investigators and Project Personnel - Information/Qualifications

Principal Investigator - Gary A. Smith, MD, DrPH. - Dr. Gary Smith is an Associate Professor of Pediatrics with joint faculty appointments in the Division of Epidemiology, College of Public Health, and in the Department of Emergency Medicine, at the Ohio State University College of Medicine. He is Director of the Center for Injury Research and Policy and is a pediatric emergency medicine physician at Nationwide Children's Hospital in Columbus, Ohio. Dr. Smith is board certified in the specialties of pediatrics and general preventive medicine and public health, and in the subspecialty of pediatric emergency medicine. In addition to his clinical training, Dr. Smith holds Master of Public Health and Doctor of Public Health degrees from the Johns Hopkins Bloomberg School of Public Health. He is immediate past chairperson of the national Committee on Injury, Violence, and Poison Prevention of the American Academy of Pediatrics (AAP) and was a member of the Initial Review Group of the National Center for Injury Prevention and Control, CDC, from 2003-2006. Dr. Smith is the principal investigator of several ongoing injury research projects at the Center for Injury Research and Policy, including the Ohio CODES Program. In this capacity, he has worked closely with the Ohio Department of Public Safety, Ohio Department of Health, Ohio Hospital Association, and other statewide organizations.

Co-Investigator - Huiyun Xiang, MD, PhD, MPH. - Dr. Xiang is an Assistant Professor of Pediatrics in the Ohio State University College of Medicine and a research faculty member in the Center for Injury Research and Policy. Dr. Xiang is an injury epidemiologist with advanced training in biostatistics. He has more than 15 years experience in large data management and statistical analysis. Dr. Xiang is the PI of several ongoing injury research projects at the Center for Injury Research and Policy, and is Co-PI of the Ohio CODES Program. He assisted the PI oversee data linkage and analysis of linked data for this project.

Co-Investigator – Jonathan I. Groner, MD. - Dr. Groner is a Clinical Associate Professor of Surgery at the Ohio State University College of Medicine. He is the Medical Director of the Level 1 Pediatric Trauma Program at Nationwide Children's Hospital, and an affiliate research faculty member in CIRP. Dr. Groner was president of the Central Ohio Trauma System, and is a member of the Ohio Emergency Medical Services Board. He is a Co-Investigator of the Ohio CODES Project. He assisted the PI with analysis and interpretation of data for this project.

Project Research Manager – Lynne Rochette, MS. - Ms. Rochette has a master degree in experimental psychology from Ohio University and is currently a doctoral degree candidate. She has experience in conducting research, performing data analysis, peer-reviewed publication, grant writing, and teaching research methods and statistics. Ms. Rochette was responsible for the day-to-day activities of the study.

Data Linkage Supervisor – Kristen Conner, MPH. - Ms. Conner had several years of data analysis and technical writing experience prior to joining the Center for Injury Research and Policy as Manager of the Ohio CODES Program. She has experience with the probabilistic data linkage methodology used by the NHTSA CODES Program and developed by Michael McGlincy, PhD, President of Strategic Matching, Inc.

Michael McGlincy, PhD - Dr. McGlincy is the creator of the CODES software that was used in this project. He founded Strategic Matching, Inc. and developed the CODES2000 and LinkSolv record linkage software products. For the last five years, he has supported implementation and use of CODES2000 and LinkSolv by various research organizations. He developed new Bayesian statistical algorithms for better record linkage and introduced a new linkage imputation methodology as an effective solution to the problem of incomplete record linkages.[3] He has a PhD in Applied Mathematics. Dr. McGlincy served as a consultant on this project.

Literature Review

MRVs include a variety of machines that may be used for different purposes. For clarity and to simplify meaning throughout this proposal, we will use the term "ATV" to refer to MRVs with 4 wheels, 3 wheels and an unknown number of wheels (but not 2 wheels), and the term "MRV" to include all motorized recreational vehicles, including ATVs and 2-wheel motorized recreational vehicles.

Background and Public Health Significance - Motorized recreational vehicles (MRVs), including all-terrain vehicles (ATVs), are responsible for many serious injuries and deaths in Ohio[1,2] and nationally. According to the U.S. Consumer Product Safety Commission (CPSC), Ohio ranks among the top third of states in the reported number of all-terrain vehicle (ATV)-related fatalities. ATV-related injuries and fatalities continue nationally at epidemic rates, especially among children younger than 16 years. Between 1985 and 2003, children younger than 16 accounted for 37 percent of all ATV-related injuries and approximately one-third of ATV-related deaths.

The most serious type of MRV-associated injury is a traumatic brain injury (TBI), which often results in death or life-long severe disability. TBI has been referred to as the "silent epidemic" by the Centers for Disease Control and Prevention (CDC) and others due to its vast incidence and pressing need for further research.[4,5] Annually, an estimated 1.4 million Americans suffer a TBI, resulting in 235 000 hospitalizations, 50 000 deaths, and $56.3 billion in direct and indirect costs.[6] By comparison, there are an estimated 175 000 Americans diagnosed with breast cancer and 44 000 diagnosed with HIV/AIDS each year.[7] TBI is the most common traumatic event involving the central nervous system, surpassing traumatic spinal cord injury by a factor of 10.[7] TBI is particularly devastating among children. TBI resulting from unintentional trauma constitutes the number one cause of mortality among Americans younger than 24 years of age, and is often the most serious consequence of nonfatal injury.[8-10] Pediatric TBI is a

substantial contributor to the health resource burden in the U.S., accounting for more than $1 billion in total hospital charges annually.[11]

Children and Motorized Recreational Vehicles - We analyzed MRV-related TBI data for Ohioans of all ages; however, children and adolescents account for a disproportionate share of the serious injuries and deaths.[1,12-15] There are no existing federal laws or safety rules regulating use of these vehicles, and Ohio has sporadic and inconsistent MRV-related safety laws affecting children. Training, licensure and minimum age requirements exist for the operation of automobiles, yet in most states, there are no comparable requirements for the operation of an MRV, including those with 2 wheels. The safe use of an MRV requires at least as much judgment, developmental maturity, and skill as needed to operate an automobile; however, adult-sized vehicles, defined as MRVs with an engine size larger than 90cc, are regularly sold to parents of children younger than 16 years, who may look to public policy for guidance regarding what is "safe" for their children. The position of the American Academy of Pediatrics (AAP) is that children younger than 16 years of age should not be allowed to operate off-road motorized vehicles, regardless of engine size or number of wheels.[14]

Traumatic Brain Injury - TBI is the most serious type of MRV-associated injury, often resulting in death or life-long severe disability. Annually, an estimated 1.4 million Americans suffer a TBI from all causes, resulting in 235 000 hospitalizations, 50 000 deaths, and $56.3 billion in direct and indirect costs.[6] TBI is the most common traumatic event involving the central nervous system, surpassing traumatic spinal cord injury by a factor of 10.[7] Motor vehicle crashes are the second-leading cause of ED visits due to TBI in the United States and the leading cause of TBI-associated hospitalization and mortality.[6] Studies investigating TBI-associated hospital charges related to external cause of injury report higher charges among individuals involved in motor vehicle crashes.[16-18] Crashes associated with MRVs are included among these motor vehicle crash cases. The CDC, Congress, and health professionals have issued numerous calls-to-arms to reduce the substantial morbidity, mortality and resource burden associated with TBI in the US.[5,16,19]

TBI is particularly devastating among children. TBIs resulting from unintentional trauma constitute the number one cause of mortality among Americans younger than 24 years of age, and are often the most serious consequences of nonfatal injuries.[8-10] Neuropsychological sequelae associated with pediatric TBI can influence key developmental processes, such as learning, emotional awareness, and social functioning.[20,21] Further, injury costs for children are often greater than those for adults, because they include expenditures for acute treatment and long-term rehabilitation, as well as loss-of-productivity for the parent or guardian.[17] Despite the immense costs, both financial and emotional, of TBI to families and society, there is a paucity of research on the resource burden associated with TBI, particularly for the estimated 64 000 pediatric hospitalizations that occur each year in the U.S.[6]

While several studies have examined trends in TBI hospitalizations and explored the psychosocial sequelae of brain-injured patients, few researchers have looked at the resource burden associated with TBI events, and fewer still have focused on pediatric TBI.[20-30] Dr. Gary Smith is a co-author of a 2006 study in *Pediatrics* that provides, for the first time, national estimates of the incidence of pediatric TBI-associated hospitalizations in the U.S., and the resource utilization associated with those hospitalizations. The inpatient charges alone identified in that study totaled more than $1 billion, making TBI one of the most costly hospital diagnoses for children.[11]

Historical Perspectives

ATVs fall under the federal regulatory jurisdiction of the CPSC. After recognizing ATVs as a significant hazard, the CPSC entered into voluntary consent decrees with ATV manufacturers in 1988, in which the manufacturers agreed to halt production of three-wheel vehicles, offer safety training to new owners, and recommend adult-sized ATV's only for operators 16 years and older. Although the consent decrees expired in 1998, three-wheel vehicles are no longer in production. However, the hazards presented by 3-wheel ATVs were quickly replaced with those of larger, faster, more powerful (engines with more cc's) 4-wheel vehicles. Safety training is not always provided to or accepted by consumers at the time of purchase. The ATV industry relies heavily on warning labels and owner's manuals to convey key safety messages about the inappropriateness and dangers of use of adult-sized ATVs by children younger than 16 years. However, an independent undercover investigation by Good Morning America found that 9 out of 10 ATV dealers knowingly sold adult-size ATV's for use by a 14-year old in violation of the current voluntary agreements between the five major ATV manufacturers and the CPSC. In 2001, at least 97% of all injured children younger than 16 were operating ATVs that were larger than the size recommended for their age. The average size of vehicles operated by children under 16 is now approximately 240 cc, even though the industry and the CPSC officially recommend that no child younger than 16 years operate an ATV with an engine larger than 90 cc. Clearly, the current voluntary approach is not working.[12]

Fatalities involving 4-wheel ATVs increased from 7% or less of all ATV-related deaths before 1985 to approximately 90% for 2003. There was a transient decrease in the estimated number of ATV-related injuries for all ages treated in emergency departments (EDs) associated with the consent decrees and halting all production of 3-wheel vehicles, followed by a steady and disturbing increase back to almost pre-1988 levels.[15] The same trend holds true for ATV-related deaths. Children under 16 years have accounted for a disproportionate one-third of the estimated injuries from 1996-2003, when they make-up just 14% of ATV users. Based on injuries per 1,000 drivers, ATV drivers younger than age 16 suffer approximately 4 times as many injuries on adult-size ATVs with engine sizes between 91 and 199cc, than do teens 16 years and older driving licensed on-road motor vehicles.[12]

Current Status in Ohio

Dr. Gary A. Smith co-authored a related article published in the March 2005 issues of *Pediatrics*.[1] This article's data on 2-wheel MRV-related injuries, collected from 6 children's hospitals across the State from 1995-2001, are the only Ohio-specific data available on this issue. The study included 182 hospitalized children with a mean age of 11.4 years (range 1-15 years). Most of the children sustained multiple injuries. Of the 152 (83.5%) patients with the presence or absence of protective devices documented, more than half (53.3%) were unhelmeted. Unhelmeted riders had significantly higher injury severity scores (ISSs) than helmeted riders (11.5 vs 8.4; p=.02), thus underscoring the importance of helmet use. Drs. Smith and Groner also co-authored a companion article on ATV-related injuries treated in 6 children's hospitals in Ohio, which was published in the June 2006 issue of *Pediatrics*.[2]

Although children cannot ride a 2-wheel MRV on a road in any state before they are age 16, they can ride off-road without a license, training, or safety equipment. Some of these vehicles are high-powered and can move at speeds well in excess of 30-40 mph. Children often lack the necessary judgment and skills to safety operate these vehicles. The severity and increasing frequency of injuries associated with 2-wheel MRV use highlight the importance of acting on this issue to prevent future injuries. A key recommendation of the March 2005 *Pediatrics* study, which echoes the position of the AAP, is that children should not operate motorbikes until they are old enough to obtain a driver's license.

Regional and National Trends

Status of Current National Agenda to Address MRV-related Injury to Children - The issue of ATV use by children younger than 16 years has received substantial national attention. In August 2002, CIRP joined a coalition to petition the CPSC to ban adult-sized ATVs for use by children younger than age 16. A report "ATV Safety Crisis: America's Children at Risk" analyzing CPSC data revealed escalating serious injuries and deaths to children associated with ATVs. The report urged the CPSC to promulgate a rule that would establish a nationwide minimum standard, provide real penalties for dealers who fail to comply, and send a clear message to parents that adult-size ATVs are inappropriate for children younger than 16 years. The report also encouraged states to regulate ATVs like automobiles by establishing minimum age standards, and requiring formal training, licensure, and helmet use. The coalition issued another report[1] in August 2003 in an effort to keep this issue in the spotlight and to document the failure of the ATV industry's voluntary approach to protect children from the hazards of ATVs. CPSC data show that the escalating and record-breaking numbers of preventable deaths and injuries to children associated with ATVs cannot be explained simply by an increase in ATV sales. Despite compelling data, the CPSC voted to deny the petition.

State Action is Needed - Because the federal government has not been willing to address ATV safety in a reasonably prompt manner, states must take action to protect children from MRV-related injuries. This

study provided the opportunity to analyze unique, Ohio-specific, linked injury data to evaluate the medical and economic impact of MRV-related TBI in Ohio. This final report provides information and recommendations for action at the state level to prevent MRV-related TBI in Ohio.

Data Considerations

Population and Methods - We linked four large statewide datasets for Ohio (Crash Information System, Emergency Medical Services Incidence Reporting System, Ohio Trauma Registry, and Emergency Department and In-patient Hospital Database for the years 2003-2006) to address the two specific aims of this study. These databases were linked using a sophisticated probabilistic linkage software application. Inclusion of the Ohio Trauma Registry for 2003-2006, and addition of data for 2004 - 2006 for the other three databases represent a substantial expansion in the scope of this research project compared with CIRP's prior MRV research funded by ODPS/EMS. In addition, this research project focuses on TBI in Ohio (Specific Aim 1) with an in-depth analysis of factors associated with TBI caused by MRV use in Ohio (Specific Aim 2). Linkage of these datasets provided a unique opportunity to evaluate the medical and economic impact of these injuries in Ohio as well as gain a critical understanding of the factors associated with MRV-related TBI.

Probabilistic Data Linkage - Records for the same cases found in the statewide datasets were linked for calendar years 2003-2006. This process builds an extensive new research database from the independent datasets. Each data source currently exists independently, and linkage of these sources allows researchers to follow individuals through the trauma system from the field through medical treatment. Probabilistic record linkage techniques were used because the datasets of interest do not include unique case identifiers common to all files. Probabilistic linkage methods were developed several decades ago and have been well evaluated in a variety of research disciplines. In more recent years, this theory and these methods have been introduced in injury research.

Ideally, all of the found links are included in the final linked dataset for research. However, most available administrative statewide trauma-related datasets lack common complete personal identifiers, or exhibit high-levels of non-response for important quasi-identifiers or analysis covariates. Many true links can have low probabilities due to misclassification or non-response. Obvious (i.e., high-probability) links between complete records can constitute a relatively small and potentially biased sample from the population of true matched record pairs. Eliminating records with missing data, or guessing what the missing data should be, weakens the data for analysis. Instead, Codes, Access, and SAS were used to address the problem by multiply-imputing complete, representative linked datasets using Markov-Chain Monte Carlo methods. After applying a Bayesian model, this process produces posterior probabilities that each candidate linked pair of records is a true match, given all of the link fields. CODES2000 is a specialized software package, implemented as a Microsoft Access application, that allows these

comparisons for large volumes of records using a hierarchical Bayesian model. This analysis generates a list of the found linked pairs of records.

Privacy and confidentiality policies are implemented for the results of the probabilistic linkage; personal and hospital identifiers are only used for linkage purposes; therefore, these sensitive variables were not included in the final datasets for statistical analyses.

IRB Approval - The Ohio Department of Public Safety and the Research Institute at Nationwide Columbus Hospital signed a Memorandum of Understanding regarding data use and confidentiality for the CODES Project. Access and use of the data for the research described in this current project was covered under this existing MOU. This research project was approved by the IRB of the Research Institute at Nationwide Children's Hospital.

Data Analyses - Our analysis involved linked data from the Ohio Trauma Registry and Emergency Department and In-patient Hospital Database, as these datasets provided information most pertinent to our specific aims. Multiple imputation was used to account for missing covariate values. Five imputed datasets were generated as in Raghunathan, et al., 2001[31], and combining rules (Rubin, 1987[32]) were employed to calculate estimates and standard errors across the datasets. The primary outcome measures of this study included medical outcomes and economic outcomes.

A series of *International Classification of Disease, 9th revision, Clinical Modification* (ICD-9-CM) diagnosis codes were used to identify TBI cases, consistent with CDC recommendations.[24,33] These TBI diagnosis codes are as follows: fracture of the vault or base of the skull (800.0-801.9); other unqualified and multiple fractures of the skull (803.0-804.9); and intracranial injury, including concussion, contusion, laceration and hemorrhage (850.0-854.1). The following diagnosis codes were not included for the definition of TBI cases because of the potential to include head lacerations and other non-TBI: injury to the optic chiasm, optic pathways, and visual cortex (950.1-950.3); and head injury, unspecified (959.01). Shaken Infant Syndrome (995.55) was also not included because it wasn't applicable to our topic of investigation.

The International Classification of Diseases, Ninth Revision (ICD-9) External Injury Codes (also known as E-codes) from the Ohio Trauma Registry dataset were used to define MRV collision and non-collision injury cases. E-codes E810 – E825 describe all motor vehicle accidents, including codes E810 – E819 that relate to motor vehicle traffic events. E820 – E825 relate to motor vehicle non-traffic events for motor vehicles being used in recreational or sporting activities. For this analysis, external injury codes for recreational motor vehicles (MRVs) E821 through E823 and E825 have been used, which include ATVs, off-highway motorcycles, off-road vehicles, motorized bicycles, and other recreational motor vehicles.

Problems and Alternative Strategies - In the 2002 Ohio Trauma Registry dataset, there was a high percentage of missing values in several variable fields needed for our probabilistic linkage strategy. This prevented the use of the 2002 dataset. Therefore, instead of linking 2002 through 2005 as we had proposed, we linked 2003 through 2006. In addition, this study used the CODES2000 software for multiple imputation and probabilistic linkage of datasets, rather than the LinkSolv software originally proposed for this research. The creator of the software (LinkSolv and CODES2000) recommended the change because both programs produce the same end result, but the CODES2000 software would allow us to combine our prior work with the linkage results for this study.

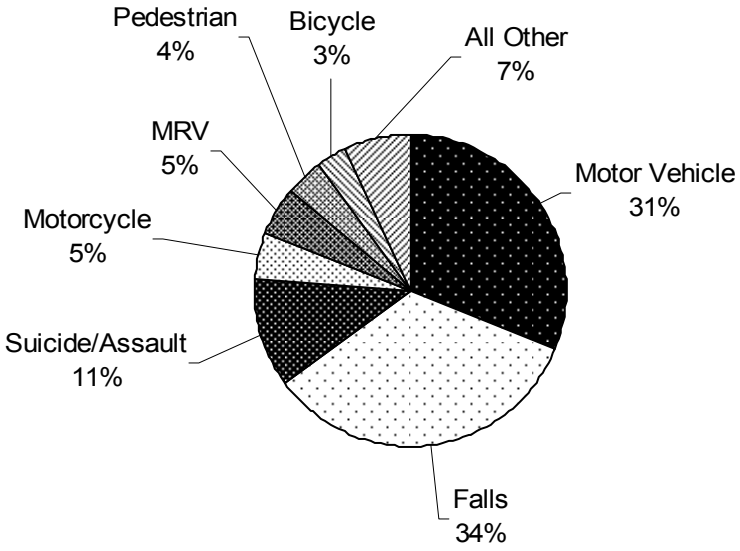
This study required us to make several decisions regarding the variables needed for analyses. First, the linkage process only allows us to match to one file in the Emergency Department and In-patient Hospital Database to the Trauma Registry. Because our project goal was to identify the final outcome of the patient receiving treatment, we removed the first hospital visit for individuals who were subsequently transferred to another hospital. This most likely resulted in an underestimate of the medical and financial impact of TBI in Ohio. Second, the Injury Severity Score (ISS) in the trauma dataset had missing values in approximately 20% of cases. Our imputation process can only impute missing data for continuous variables where every point on the scale is assigned a valid meaning. Because this is not the case for ISS, we decided to calculate ISS from the ICD-9 diagnosis codes using ICDMAP-90 (The Johns Hopkins University & Tri-Analytics, Inc., Baltimore, MD). This resulted in less than 1% missing values for our ISS variable. Third, the Trauma Registry contains information for the Glasgow Coma Scale (GCS) gathered at the scene or taken upon arrival in the hospital. Some patients had an invalid GCS in the hospital, because they were intubated or sedated at the time of assessment. For these individuals, we used a valid scene GCS if the measure was available. However, many individuals did not have a GCS at the scene, because they entered the hospital without EMS involvement or were intubated or sedated at the scene. We assigned these individuals to a unique category (unknown), because we believe this is a meaningful group for comparison.

Limitations - In addition to the data considerations mentioned above, this study has several limitations. The Trauma Registry does not include all incidents of injury for the state of Ohio. To be included in the Trauma database, individuals must have been admitted for at least 48 hours, transferred into or out of the hospital, pronounced dead on arrival, or died at any point during care in the hospital. Thus, only individuals with severe injuries requiring extensive medical care were included in this analysis. Further, people who were treated or died at the scene are not included in this analysis. Therefore, our analysis underestimates the financial and economic burden of TBI injuries in Ohio. We were also unable to calculate injury rates, because we did not have complete exposure data.

Researcher Findings

Traumatic Brain Injury in Ohio - From 2003 through 2006, there were 26,063 trauma registry cases of TBI in Ohio, including 1,165 cases of MRV-related TBI. The two most frequent causes of injury were motor vehicle crashes and falls, accounting for 65% of all TBI cases (see figure 1). Although only 23% of all TBIs occurred in a rural area, 35% of all MRV-related TBIs occurred in a rural area. Roughly 50% of all TBIs and MRV-related TBIs occurred on a street or highway.

Figure 1. Cause of Traumatic Brain Injury in Ohio, 2003 - 2006.



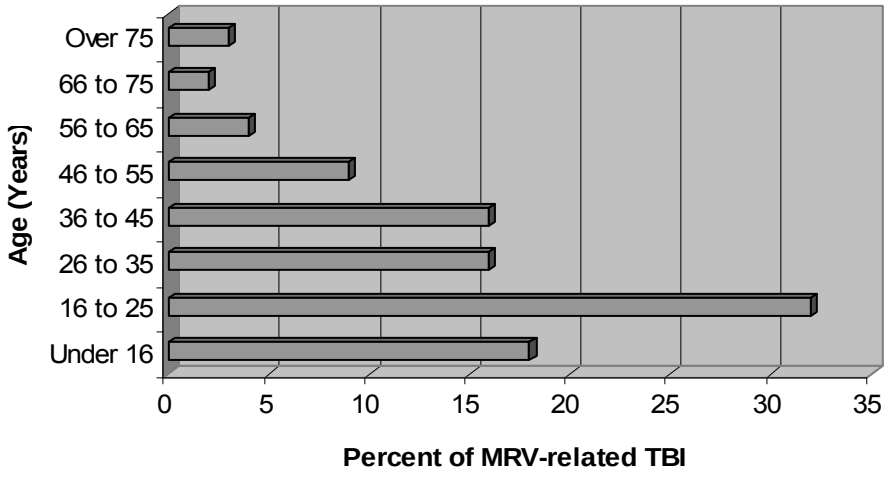
During 2003 through 2006, there were 3,558 TBIs among children under the age of 16 years (see Table 1). Of these injuries, 212 (6%) incidents were MRV-related. Males sustain a TBI more often than females. The average age for a non-TBI patient was 49 years of age (median 48). However, the average age for all TBI patients was 43 years (median 40), and was 30 years (median 25) for MRV-related TBI patients.

Table 1. Demographic Profile of Trauma Patients in Ohio, 2003 - 2006.

	All TBI	MRV-TBI only	All Trauma
	Number (%)	Number (%)	Number (%)
Gender			
Male	17,026 (65%)	898 (77%)	55,488 (57%)
Female	9,037 (35%)	267 (23%)	41,732 (43%)
Race			
White	21,813 (84%)	1076 (92%)	80,497 (83%)
Non-White	4,250 (16%)	89 (8%)	16,723 (17%)
Age			
Under 16	3,558 (14%)	212 (18%)	12,762 (13%)
16 – 25 years	4,949 (19%)	376 (32%)	14,083 (15%)
26 – 35 years	3,042 (12%)	187 (16%)	9,987 (10%)
36 – 45 years	3,314 (13%)	186 (16%)	11,566 (12%)
46 – 55 years	2,094 (12%)	100 (9%)	11,415 (12%)
56 – 65 years	1,838 (8%)	43 (4%)	8,252 (9%)
66 – 75 years	2,635 (7%)	28 (2%)	8,028 (9%)
76 and older	1,515 (16%)	11 (3%)	8,646 (22%)

Although individuals age 16 to 25 years comprise only 15% of all trauma cases, they have the largest percentage of TBI (19%) and MRV-related TBI (32%) compared with other age groups (see figure 2). MRV riders 16 to 25 years of age are 1.8 times more likely to suffer a MRV-related TBI compared with MRV riders over the age of 35 years. Compared with MRV riders over 35 years of age, MRV riders under the age of 16 years are 1.3 times more likely to sustain a MRV-related TBI.

Figure 2. MRV-Related TBI in Ohio, 2003 - 2006.



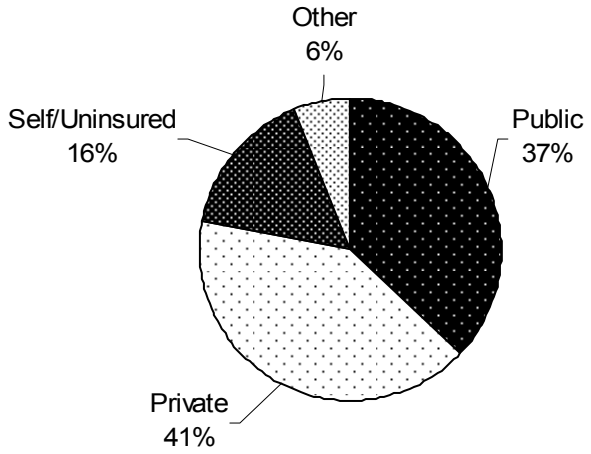
Economic Impact of TBI - Hospital charges were $37,000 on average for a TBI, whereas hospital charges for non-TBIs were on average approximately $23,700. Hospital charges for MRV-related TBI were approximately $36,000, similar to that for all TBIs (see Table 2). Most hospital charges are paid by

private funding sources. However, public funds still covered approximately 37% of hospital charges for patients with a TBI (see figure 3). The average annual hospital charges in Ohio for TBI and MRV-related TBI were approximately $241,081,000 and $10,461,000, respectively.

Table 2. Hospital Charges in Ohio, 2003 - 2006.

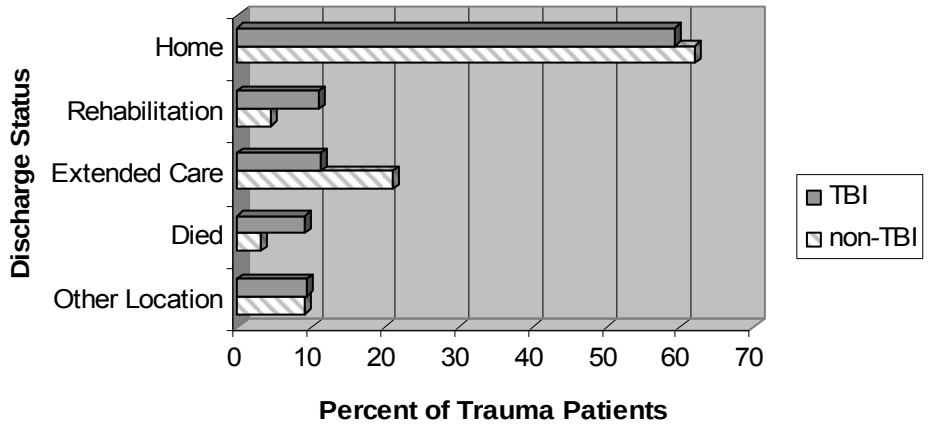
	Mean	Median
TBI	$37,000	$20,164
MRV-related TBI	$35,917	$19,731
Non-TBI	$23,737	$14,135

Figure 3. Payor Source for Hospital Charges for TBI Patients, Ohio 2003 - 2006.



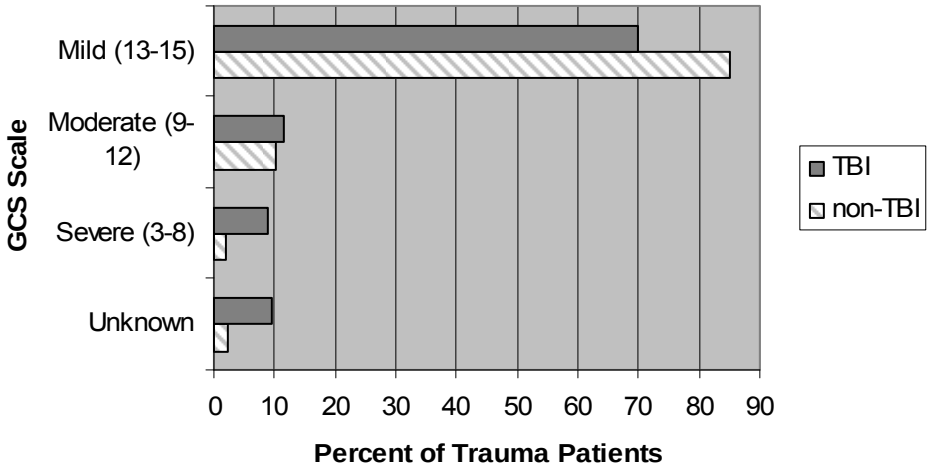
Medical Outcome of TBI - During 2003 through 2006, there were 2,345 fatalities due to TBI. MRV-related injuries were responsible for 63 (3%) of these deaths, with 5 fatalities occurring among children under the age of 16 years, and 20 fatalities occurring among individuals age 16 to 25 years. A larger percentage of non-TBI patients were discharged to nursing/extended care facilities compared with TBI patients (21% vs. 11%). However, 11% of TBI patients needed rehabilitation care and 9% died, compared with non-TBI patients, among whom 5% needed rehabilitation and 3% died (see figure 4).

Figure 4. Discharge Disposition by TBI Status, Ohio 2003 - 2006.



On average, TBI patients had a slightly longer hospital stay compared with patients without a TBI (mean: 6.9 vs. 5.8 days). TBI patients also had a longer average ICU length of stay compared with non-TBI patients (mean: 2.1 vs. 0.7 days), and approximately 37% of TBI patients were admitted to the ICU compared with 14% of non-TBI patients. Average number of days of ventilator use was also higher among TBI patients compared with non-TBI patients (mean: 1.3 vs. 0.4 days), and only 5% of non-TBI patients required mechanical ventilation, whereas 21% of TBI patients required ventilation.

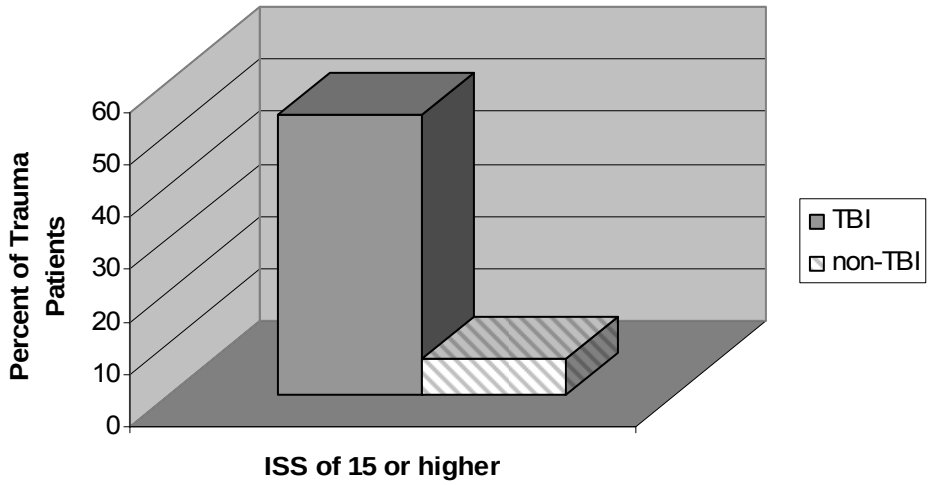
Figure 5. Head Injury Severity by TBI Status, Ohio 2003 - 2006.



As figure 5 illustrates, a larger percentage of TBI patients had severe deficits in level of consciousness (Glasgow Coma Scale 3 - 8) compared with non-TBI patients (9% vs. 2%). Additionally, almost 10% of TBI patients had unknown Glasgow Coma Scale scores, because they were intubated or sedated at the

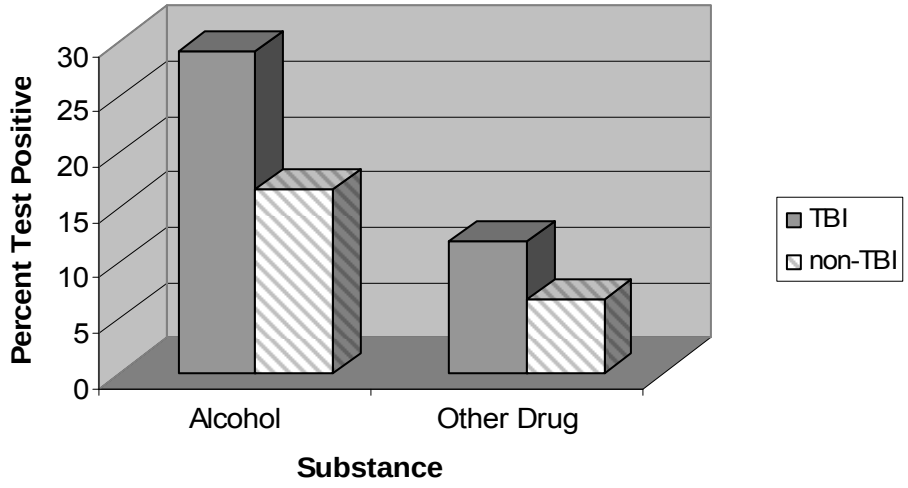
time of assessment, compared with only 2% of non-TBI patients. Only 7% of individuals without a TBI had a high Injury Severity Score (ISS ≥ 15), whereas 53% of individuals with a TBI had a high Injury Severity Score (see figure 6).

Figure 6. Injury Severity Score by TBI Status, Ohio 2003 - 2006.



Substance Use Behaviors - Blood alcohol tests confirmed alcohol use in 29% of all TBI cases compared with 17% of non-TBI cases (see figure 7). Injured MRV riders with blood test-confirmed alcohol use were 1.8 times more likely to sustain a TBI than those without documented alcohol use. Additionally, injured MRV riders with a positive blood alcohol test were 1.7 times more likely to be admitted to a rehabilitation facility than injured MRV riders without documented alcohol use. Approximately 12% of TBI patients tested positive for other drugs besides alcohol compared with 7% of non-TBI cases.

Figure 7. Substance Use by TBI Status, Ohio 2003 - 2006.



Protective Behaviors - Among individuals with motor vehicle-related injuries, a smaller percentage of TBI patients used motor vehicle passenger safety equipment (air bag and/or seat belt) than non-TBI patients (see figure 8). About 15% of TBI patients were wearing a helmet while riding a MRV at the time of the injury compared with 24% of non-TBI patients. In addition, approximately 22% of TBI cases were wearing a helmet while riding a motorcycle at the time of the crash compared with 35% of non-TBI patients (see figure 9). Injured MRV riders not wearing a helmet at the time of injury were 1.5 times more likely to sustain a TBI than those wearing a helmet. Additionally, death due to a MRV-related injury was 2.5 times more likely for injured MRV riders not wearing a helmet at the time of injury compared with those wearing a helmet. Less than 2% of all injured motorcycle, MRV, and bicycle riders used other safety protection devices, such as eye protection, protective clothing, or padding.

Figure 8. Protective Behaviors by TBI Status, Ohio 2003 - 2006.

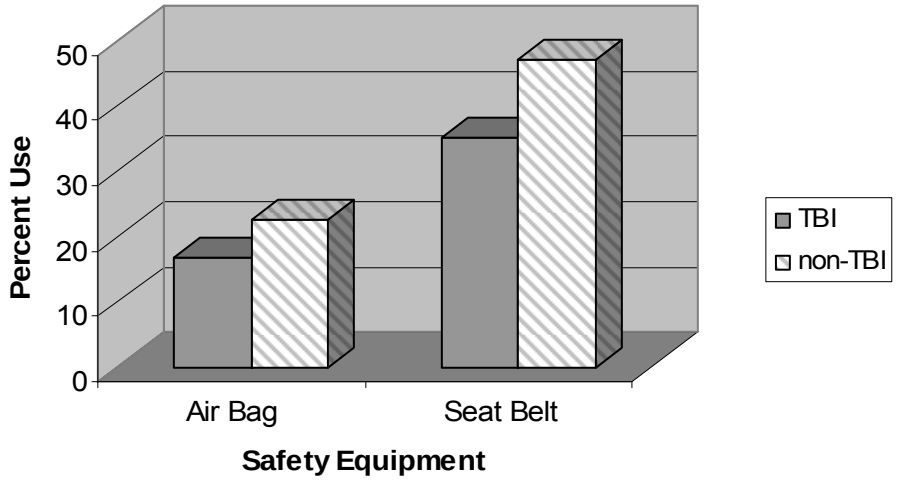
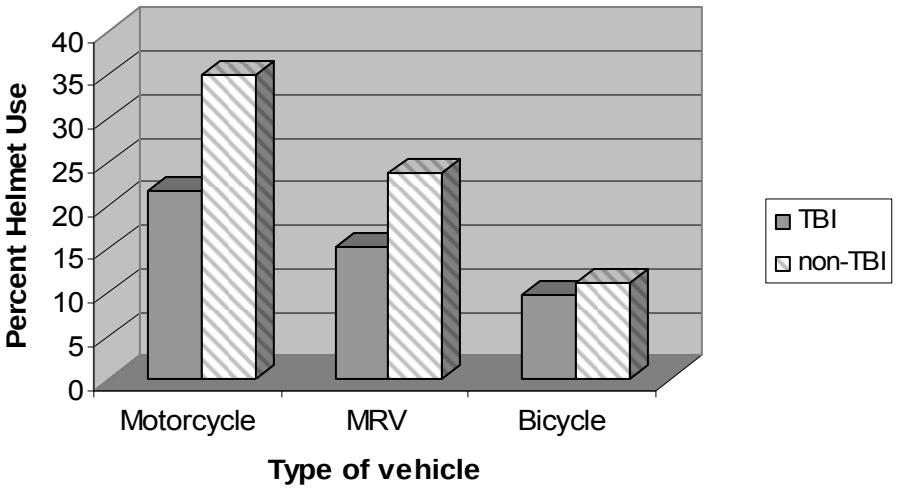


Figure 9. Helmet Use by TBI Status, Ohio 2003 - 2006.



Conclusions

Motor vehicle crashes and falls account for the majority (65%) of TBI cases in Ohio, while MRVs are associated with slightly less than 5% of TBIs statewide. The average annual hospital charges in Ohio for TBI and MRV-related TBI are approximately $241,081,000 and $10,461,000, respectively. TBI occurs to individuals of all ages; however, among trauma patients, younger individuals are more likely to sustain a TBI than older individuals. This is especially the case for MRV-related TBI, where 50% of the patients are under the age of 25 years. Hospital charges are greater for TBIs than non-TBIs, averaging approximately $13,000 more in hospital charges for a TBI. TBI patients also have longer average hospital stays, more admissions to the intensive care unit (ICU), and longer average ICU length of stays. Substance use also is associated with TBI outcome. Alcohol use is higher among individuals with a TBI than individuals with a non-TBI. Injured MRV riders with blood test-confirmed alcohol use are more likely to sustain a TBI and be admitted to a rehabilitation facility than injured MRV riders without documented alcohol use. Helmet use is a valuable protective safety behavior. Among injured MRV riders, a smaller proportion of those with TBI were wearing a helmet at the time of injury than those with a non-TBI. Injured MRV riders not wearing a helmet at the time of injury are more likely to sustain a TBI or die than those wearing a helmet. Thus, helmet use reduces the likelihood of a TBI and death among injured MRV users.

Recommendations

The findings of this study reinforce the recommendations made one year ago by the Center for Injury Research and Policy in its All-Terrain Vehicle Safety Report. We recommend a combination of education and legislative action to decrease the morbidity and mortality due to MRV-related TBI in Ohio. Specifically, we recommended the following legislative actions: (1) institute a law requiring use of a helmet at all times while operating or riding a MRV, (2) prohibit passengers on all MRVs unless they are specifically designed to carry more than one person, (3) prohibit the use of MRVs by children under 16 years of age as recommended by the American Academy of Pediatrics, and (4) require all MRV owners and operators to take a safety class prior to operating a MRV.

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