Factors Associated with Pediatric Mortality from Motor Vehicle Crashes in the United States: A State-Based Analysis

Lindsey L. Wolf, MD, MPH[1,2], Ritam Chowdhury, MBBS, MPH, PhD, SM[1], Jefferson Tweed, BS[3], Lori Vinson, RN, MSN[3], Elena Losina, PhD[4], Adil H. Haider, MD, MPH[1,2], and Faisal G. Qureshi, MD, MBA[3,5]

Objective To examine geographic variation in motor vehicle crash (MVC)-related pediatric mortality and identify state-level predictors of mortality.

Study design Using the 2010-2014 Fatality Analysis Reporting System, we identified passengers <15 years of age involved in fatal MVCs, defined as crashes on US public roads with ≥1 death (adult or pediatric) within 30 days. We assessed passenger, driver, vehicle, crash, and state policy characteristics as factors potentially associated with MVC-related pediatric mortality. Our outcomes were age-adjusted, MVC-related mortality rate per 100 000 children and percentage of children who died of those in fatal MVCs. Unit of analysis was US state. We used multivariable linear regression to define state characteristics associated with higher levels of each outcome.

Results Of 18 116 children in fatal MVCs, 15.9% died. The age-adjusted, MVC-related mortality rate per 100 000 children varied from 0.25 in Massachusetts to 3.23 in Mississippi (mean national rate of 0.94). Predictors of greater age-adjusted, MVC-related mortality rate per 100 000 children included greater percentage of children who were unrestrained or inappropriately restrained ($P < .001$) and greater percentage of crashes on rural roads ($P = .016$). Additionally, greater percentages of children died in states without red light camera legislation ($P < .001$). For 10% absolute improvement in appropriate child restraint use nationally, our risk-adjusted model predicted >1100 pediatric deaths averted over 5 years.

Conclusions MVC-related pediatric mortality varied by state and was associated with restraint nonuse or misuse, rural roads, vehicle type, and red light camera policy. Revising state regulations and improving enforcement around these factors may prevent substantial pediatric mortality. *(J Pediatr 2017;187:295-302).*

Unintentional injury is the leading cause of pediatric death in the US, and motor vehicle crashes (MVCs) are the most common cause of injury.[1] Over the past 20 years, many studies have analyzed individual, person-level data and identified several risk factors for MVC-related mortality in children, including nonuse of restraints,[2-5] front seat position,[4-6] alcohol-impaired drivers,[7-10] younger driver age,[9] high speed roads,[9,11] and rural roads.[12,13] In 2011, informed by this research, the American Academy of Pediatrics published specific guidelines regarding the strongest and most modifiable predictors—namely, child restraints and seat position.[14] Prior guidelines have also addressed alcohol use by drivers.[15] Although these recommendations have been implemented in part by some states, no state has implemented them fully.[16]

Further, no prior study has examined trends in MVC-related pediatric mortality across states and factors associated with geographic variation at the state or regional level. This geographic variation is important because laws regarding child traffic safety remain within the state domain.[17] It is vital, therefore, to understand how state-level regulations and their implementation and enforcement impact MVC-related pediatric mortality. We hypothesized that state-level policies related to child traffic safety would be associated with state mortality rates. Our objectives were to assess for variation in MVC-related pediatric mortality by state and region and to explain the sources of such variation.

Methods

We performed a retrospective analysis of data to inform state-level policy. We compiled our analytic dataset from multiple sources. The primary source was the

AAMR	Age-adjusted, mean MVC-related pediatric mortality per 100 000 children
FARS	Fatality Analysis Reporting System
MVC	Motor vehicle crash

From the [1]Center for Surgery and Public Health, A Joint Venture of the Brigham and Women's Hospital, Harvard Medical School, Harvard T.H. Chan School of Public Health; [2]The Division of Trauma, Burns, and Surgical Critical Care, Department of Surgery, Brigham and Women's Hospital, Boston, MA; [3]Children's Medical Center of Dallas, Part of Children's Health[SM], Dallas, TX; [4]The Orthopaedic and Arthritis Center for Outcomes Research and Policy, Innovation Evaluation in Orthopedic Treatments Research Center, Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA; and [5]Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX

Supported by the American College of Surgeons Resident Research Scholarship (to L.W.) and the US National Institute of Health/National Institute of Arthritis and Musculoskeletal and Skin Diseases (K24AR057827-02 [to E.L.]). A.H. is the PI of a contract (AD-1306-03980) with the Patient-Centered Outcomes Research Institute entitled "Patient-Centered Approaches to Collect Sexual Orientation/Gender Identity in the ED" and a Harvard Surgery Affinity Research Collaborative (ARC) Program Grant entitled "Mitigating Disparities Through Enhancing Surgeons' Ability To Provide Culturally Relevant Care." The other authors declare no conflicts of interest.

Portions of this study were presented as an oral presentation at the American Academy of Pediatrics National Conference & Exhibition in San Francisco, California, October 21-25, 2016.

http://dx.doi.org10.1016/j.jpeds.2017.04.044

Fatality Analysis Reporting System (FARS), a nationwide census providing publicly available data on fatalities associated with MVCs. The FARS includes all fatal crashes in the US, defined as crashes that occur on a public road and result in ≥1 death (adult or pediatric) within 30 days. Data collection is supervised by the National Highway Traffic Safety Administration and data are compiled from various documents in each state, including police accident reports, death certificates, state vehicle registration files, medical examiner reports, state driver licensing files, state highway department data, emergency medical service reports, and vital statistics. Data are subjected to checks for acceptable range values and consistency, as well as quality checks.[18] We obtained annual US population size estimates by age, state, and region, and the percentage of households with a vehicle from the US Census.[19,20] We compiled state-level policies relevant to child traffic safety from the Governors Highway Safety Association, the Insurance Institute for Highway Safety (a US nonprofit research organization funded by auto insurers), and the medical and legal literature.[17,21,22] We assembled data from 2010 to 2014 to coincide with the most recently available FARS data.

We defined a study cohort using person-level data from children <15 years of age riding in a passenger vehicle involved in a fatal crash (**Figure 1**; available at www.jpeds.com). Passenger vehicles are defined by the National Highway Traffic Safety Administration as cars, sport utility vehicles, vans, and pickup trucks with a gross weight of ≤10 000 pounds.[18,23] We excluded children classified as drivers, passengers on a motorcycle/bicycle, or pedestrians, as well as children in an unenclosed passenger or cargo area, the vehicle exterior, or a trailing unit. We made these exclusions to focus on state-level policies, such as guidelines for restraint use, that would apply to all children in our study population. We used a complete case analysis approach for the individual observations, excluding observations with missing data for key variables from all analyses. Data were missing for <5% of observations for all variables except for restraint use/misuse, which was missing for 6% of observations.

Our primary outcome was state-based, age-adjusted, mean MVC-related pediatric mortality per 100 000 children (AAMR) between 2010-2014, defined as 30-day mortality from the day of the crash. We calculated age-adjusted mortality rates per 100 000 children for each state using census information on the pediatric population for 5 age groups (0-2, 3-5, 6-8, 9-12, or 13-14 years of age) within each state, standardized by the population within these age groups in the US overall. Age groups were selected based on recommended seating within a motor vehicle at different ages. We then obtained mean mortality rates by averaging the annual rates over the 5-year period of 2010-2014. Owing to state-level differences in vehicle ownership and the amount of time children may spend as passengers in a vehicle, we considered a secondary outcome, the percentage of children who died of those involved in a fatal crash.[20] We calculated both outcomes by region (Midwest, Northeast, South, West) and nationally.

To explain state-level variation in mortality rates, we compiled an extensive list of variables potentially related to MVC-related pediatric mortality, including passenger, driver, vehicle, crash, and state policy characteristics (**Appendix**; available at www.jpeds.com). Most person-, vehicle-, and crash-level variables were used as defined in the FARS. Of note, the FARS dataset reported type of restraint and any indication of misuse of the restraint system. Additionally, we defined several variables. Child passengers riding in the front seat were deemed appropriate or inappropriate based on the American Academy of Pediatrics guidelines that children <13 years of age should ride in the rear seats of vehicles.[14] Vehicle type was categorized as car, sport utility vehicle, van/minivan, pickup truck, or vehicle larger than a pickup truck. Crashes occurring over the weekend were defined as those between Friday 5 p.m. and Monday 6 a.m. Crashes occurring during the day were defined as those between 6 a.m. and 6 p.m.[24] We modeled state speed and red light camera policy using dummy variables (state legislation present vs not present, prohibited vs not prohibited, limited vs not limited, permitted vs not permitted) as well as by current use patterns (in use vs not in use). We categorized the variables into 4 main topical groups: (1) restraints or seat position,[2,3,6,9,23,25] (2) speeding or traffic restrictions,[8,9,11,23] (3) driving under the influence of alcohol,[7-10] and (4) availability of pediatric trauma centers and trauma systems.[26-31]

Statistical Analyses

We performed an ecological study using US state as our unit of analysis. We summarized person-level data for all children meeting the inclusion and exclusion criteria to obtain mean state-level values for each variable. We used multivariable linear regression to identify state characteristics associated with greater AAMR or percentage of children who die when involved in a fatal crash. For each outcome, we used stepwise model building; this approach allowed us to obtain the most parsimonious model that represented the geographic variation of MVC-related pediatric mortality without concern for overfitting the data. We included all identified variables of interest in the initial model-building process for each outcome.

We first assessed Pearson correlation coefficients between each outcome and each potential continuous predictor. We identified continuous variables that met 2 criteria: (1) correlation with the outcome, expressed by Pearson correlation of >0.3 or <–0.3 and (2) $P \leq .10$. Variables that met these criteria were included in a correlation matrix; we removed highly collinear variables (bivariate Pearson correlation ≥ 0.6), keeping the variable with the highest Pearson correlation with the outcome in the model in each instance of collinearity. For categorical and binary variables, we used ANOVA and *t*-tests, respectively, to identify variables with an association with the outcome with a P value of ≤.10. We included all selected variables in an initial model, using a process of stepwise selection to remove nonsignificant variables ($P > .10$) until we obtained a final model for each outcome. In all models for the primary outcome, the percentage of households with a vehicle was included regardless of significance owing to its likelihood to be a confounder.

Analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina). A 2-sided P value of .05 was used to determine