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Mapping pediatric injuries to target prevention, education, and outreach

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ABSTRACT

Background: Initiatives exist to prevent pediatric injuries, but targeting these interventions to specific populations is challenging. We hypothesized that mapping pediatric injuries by zip code could be used to identify regions requiring more interventions and resources.
Methods: We queried the trauma registries of two level I trauma centers for children 0–17 years of age injured between 2009 and 2013 with home zip codes in our state. Maps were created to identify outlier zip codes. Multivariate linear regression analysis identified predictors within these zip codes.
Results: There were 5380 children who resided in the state and were admitted for traumatic injuries during the study period, with hospital costs totaling more than 200 million dollars. Choropleth mapping of patient addresses identified outlier zip codes in our metro area with higher incidences of specific mechanisms of injury and greater hospital charges. Multivariate analysis identified demographic features associated with higher rates of pediatric injuries and hospital charges, to further target interventions.
Conclusions: We identified outlier zip codes in our metro area with higher frequencies of pediatric injuries and higher costs for treatment. These data have helped obtain funding for prevention and education efforts. Techniques such as those presented here are becoming more important as evidence based public health initiatives expand.
Level of evidence: Type of Study: Cost Effectiveness, II.

Traumatic injuries account for significant morbidity, mortality, and economic burden in the United States. Unintentional injuries are the single greatest cause of death for individuals 1–44 years of age [1], and annual rates of non-fatal injury are as high as 13% in this age bracket [2]. These injuries are responsible for billions of dollars in annual medical care costs [3], and many of these injuries are preventable. This is especially true of children, for whom there are several proven ways to reduce both the likelihood and severity of traumatic injuries [4].

In our metro area there are numerous childhood injury prevention and outreach programs. The application of prevention efforts is, however, somewhat uneven and largely dictated by available resources and personnel in a given area. This is because no specific data exist regarding the locations of greatest need. We hypothesized that certain zip codes within our metro area would have higher frequencies of pediatric traumatic injuries and higher hospital charges for the treatment of these injuries. We further hypothesized that injury related predictors within these zip codes could be identified. To study this, we systematically examined all children treated for traumatic injuries at two level-1 trauma centers, and mapped them by zip code of residence.

1. Materials and methods

After institutional review board approval, we queried the trauma databases of two pediatric trauma centers (PTC) (Children's Hospital Colorado (PTC level 1) in Aurora, Colorado and Denver Health Medical Center (PTC level 2) in Denver, Colorado) for all children aged 0–17 years who were evaluated in the emergency department or directly admitted as an inpatient following traumatic injuries from 1/2009 to 9/2013, and had a known home zip code in the state of Colorado. Children with zip codes associated with P.O. boxes were excluded from this study (n = 8). Next, we identified children whose home zip code was in one of two adjacent cities, Denver or Aurora, Colorado, where 20% of the state's population reside. All subsequent analysis focused on this population. According to the Colorado Department of Public Health and Environment, 80% of traumatically injured children who were living in Denver or Aurora, Colorado during the study period went to one of the two hospitals in this study. Cost data were calculated using total patient charges for the hospitalization. Data were available for all categories, except where otherwise noted.

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1.1. Mapping

Choropleth maps were created to identify outlier zip codes for pediatric injuries in these cities. Choropleth maps use shading relative to the measurement of a given variable and provide a means to visualize variation across a region. Choropleth maps were created using zip code and primary and secondary road state shape files downloaded from the U.S. census bureau (2010 TIGER/Line Shapefile: Zip Code Tabulation Areas, Colorado; 2013 TIGER/Line Shapefile, Colorado, Primary and Secondary Roads). These shape file data were overlaid atop satellite imagery of the region downloaded from the Earth Science Data and Information System Project [5,6]. A computer script was written in Python by the first author to "color in" the choropleth framework with the relevant data from the trauma database using trauma codes. This computer script is available upon request to any interested party.

1.2. Theory and calculation

Zip code demographics from the 2010 census and the 2008–2012 American Community Survey were used for comparison [7]. Demographics used in our analyses included median household income, racial demographics, percent owner occupied housing, percent with some college education, percent households married with children and single parents, and total population. Demographic predictors of pediatric traumatic injuries in specific zip codes were then identified using univariate and multivariate linear models. Because of nonnormal distribution of outcome variables, all outcome variables were log-transformed (after addition of 1×10^{-11} to all values so that zero values could be log-transformed) prior to analysis. Statistical differences were considered significant if the probability of a type I error was <5% ($p < 0.05$). All analyses were performed using SAS version 9.4 (Cary, NC).

2. Results

2.1. Demographics

We identified 5380 children who were Colorado residents treated for a traumatic injury during the study period (332 different zip codes). Hospital charges for this group during the study period totaled $201 million. Fifty-eight (1.1%) injuries were fatal. More deaths were related to nonaccidental (abusive) trauma than any other mechanism (26/58, 44.8%), and motor vehicle crashes accounted for the greatest proportion of unintentional deaths (9/32, 28.1%). More than half of the children identified (2730, 50.7%) lived in the immediate metro area consisting of the cities of Denver and Aurora, Colorado (53 zip codes). Demographics of these children are presented in Table 1. The majority of these children were Caucasians, males, and children with minor injuries

Table 1
Descriptive statistics.

Demographic	State (n = 5380)	2-city metro area (n = 2730)
Male (%)	3428 (63.7)	1755 (64.2)
Age in years (STE)	6.9 (0.1)	6.8 (0.1)
ISS (n = 5327) (STE)	7.2 (0.1)	6.6 (0.1)
Race, n (%)	5101	2596
Caucasian	3146 (58.5)	1291 (49.7)
Hispanic	1267 (23.6)	774 (29.8)
African American	305 (5.7)	271 (10.4)
Asian	117 (2.2)	67 (2.6)
Other	266 (4.9)	194 (7.5)
Insurance type, n (%)	4828	2460
Private	2746 (51.0)	1136 (46.2)
Medicaid	2007 (37.3)	1269 (51.6)
None	75 (1.4)	55 (2.2)
Length of stay (n = 4859), days (STE)	2.4 (0.1)	2.1 (0.1)
Charges/patient, dollars (STE)	$37,382 (1322)	$33,969 (1744)
Mechanism, n (%)	5040	2707
Falls	2074 (41.1)	1131 (41.8)
Motor vehicle crashes	408 (8.1)	221 (8.2)
Sports related	348 (6.9)	283 (10.5)
Bicycle related	320 (6.3)	159 (5.9)
Burns	287 (5.7)	136 (5.4)
Non-accidental	246 (4.9)	119 (4.4)
Auto-pedestrian	203 (4.0)	145 (5.4)
Trampoline related	136 (2.7)	48 (1.8)
Gunshot wounds	55 (1.0)	38 (1.4)
Fatal injuries, n (%)	58 (1.1)	37 (1.4)
Non-accidental	26 (44.8)	15 (40.5)
Motor vehicle crashes	9 (15.5)	4 (10.8)

STE = standard error; ISS = injury severity score.

2.2. Maps

Choropleth maps were created to identify zip codes in our immediate metro area that had higher frequencies of pediatric traumatic injuries, including burns, nonaccidental traumas, and motor vehicle, bicycle, trampoline, and auto-pedestrian related injuries. Fig. 1 shows a sample of the maps that were created. For each injury type, there were outlier zip codes with a higher proportion of injuries. We also mapped total charges for treatment of all pediatric traumatic injuries in each zip code (Fig. 2), and identified outliers. Four out of 53 zip codes accounted for 27% of all charges in the immediate metro area; two zip codes had average charges of over one million dollars per year for the treatment of pediatric injuries.

2.3. Multivariate linear regression analysis

Multivariate linear regression analysis was used to identify predictors of pediatric injuries by zip code. Demographic data from the US census bureau were used to adjust for confounding factors. Higher rates of pediatric traumatic injuries were associated with zip codes that had larger Hispanic populations, fewer owner occupied homes, and more married couples with children (Table 2). Higher total hospital charges were associated with zip codes that had fewer owner occupied homes, more married couples with children, and higher populations (Table 3). Demographic factors that were predictive of higher rates of specific types of traumatic injury were also identified. We found that zip codes with greater populations had higher rates of burn injuries, auto-pedestrian injuries, and sports related injuries when compared to zip codes with fewer residents (Table 4).

2.4. Outcomes

Data for bicycle related injuries, auto-pedestrian accidents, and teenagers in motor vehicle crashes were presented to the state department of transportation. As a result, 5 different elementary schools located in the zip codes of greatest need were given grant awards to fund expanded bicycle and pedestrian safety education. A grant was also awarded for teen driver safety education and outreach in the metro area.

3. Discussion

We examined types, frequencies, and costs of pediatric traumatic injuries by zip code level to identify populations that would benefit most from injury prevention efforts. Several of our findings mirror those found in the CDC's Childhood Injury Report [4], including a large number of falls, and motor vehicle crashes accounting for the majority of unintentional fatal injuries. Choropleth mapping allowed the identification of outlier zip codes for both higher frequencies of specific types of pediatric injuries, and higher hospital charges for the treatment of pediatric injuries. Multivariate analysis identified predictive demographic features that were associated with higher rates and costs for pediatric injury, including zip codes that had fewer owner occupied homes, more married couples with children, and higher overall populations. This