Journal of Trauma and Acute Care Surgery, Publish Ahead of Print
DOI: 10.1097/TA.0000000000001883

Mapping areas with concentrated risk of trauma mortality: a first step toward mitigating geographic and socioeconomic disparities in trauma

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Conflicts of Interest and Sources of Funding:

M. P. Jarman's work on this study was funded by a National Research Service Award from the Agency for Healthcare Research Quality (T32HS000029) and by the Johns Hopkins Center for Injury Research and Policy (William Haddon Jr. Fellowship). She is currently supported by a research grant from the Center for Orthopaedic Trauma Advancement ("Treatment of injury in the United States: Projections for an ideal system of trauma care").

E. R. Haut is the primary investigator of a grant from the Agency for Healthcare Research and Quality (AHRQ) (1R01HS024547-01, "Individualized Performance Feedback on Venous Thromboembolism Prevention Practice"). He is also a co-investigator for grants from the National Institutes of Health National Heart, Lung, and Blood Institute (NIH-NHLBI) (1R21HL129028-01A1, "Analysis of the impact of missed doses of venous thromboembolism prophylaxis") and The Henry M. Jackson Foundation, Uniformed Services University of the Health Sciences (HU0001-14-0038, "Validation of Training for Cricothyroidotomy"). Dr. Haut is the primary investigator of two contracts with The Patient-Centered Outcomes Research Institute (PCORI) (CE-12-11-4489, "Preventing Venous Thromboembolism: Empowering Patients and Enabling Patient-Centered Care via Health Information Technology" & DI-1603-34596, "Preventing Venous Thromboembolism (VTE): Engaging Patients to Reduce Preventable Harm from Missed/Refused Doses of VTE Prophylaxis"), and co-investigator for the PCORI contract titled "A Randomized Pragmatic Trial Comparing the Complications and Safety of Blood Clot Prevention Medicines Used in Orthopaedic Trauma Patients" (PCS-1511-32745). Dr. Haut receives royalties from Lippincott, Williams, Wilkins for a book - "Avoiding Common ICU Errors."

For remaining authors, no conflicts were declared.

Conference Presentations:

Presented at the 31st Annual Meeting of the Eastern Association for the Surgery of Trauma, January 9-13, 2018 in Orlando, FL

Study Funding Disclosure:

This study was funded by the Agency for Healthcare Research Quality (T32HS000029).

ABSTRACT

Background: Many rural, low income, and historically underrepresented minority communities lack access to trauma center services, including surgical care and injury prevention efforts. Along with features of the built and social environment at injury incident locations, geographic barriers to trauma center services may contribute to injury disparities. This study sought to classify injury event locations based on features of the built and social environment at the injury scene, and to examine patterns in individual patient demographics, injury characteristics, and mortality by location class.

Methods: Data from the 2015 Maryland Adult Trauma Registry and associated prehospital records (n = 16,082) were used in a latent class analysis of characteristics of injury event locations, including trauma center distance, trauma center characteristics, land use, community-level per capita income, and community-level median age. Mortality effects of location class were estimated with logistic regression, with and without adjustment for individual patient demographics and injury characteristics.

Results: Eight classes were identified: rural, exurban, young suburban, aging suburban, inner suburban, urban fringe, high income urban core, and low income urban core. Patient characteristics and odds of death varied across classes. Compared to inner suburban locations, adjusted odds of death were highest at rural (OR = 1.98, 95% CI: 1.36, 2.88), young suburb (OR = 1.57, 95% CI: 1.14, 2.17), aging suburb (OR = 1.36, 95% CI: 1.04, 1.78), and low income urban core (OR = 1.38, 95% CI: 1.04, 1.83) locations.

Conclusion: Injury incident locations can be categorized into distinguishable classes with varying mortality risk. Identification of location classes may be useful for targeted primary prevention and treatment interventions, both by identifying geographic areas with the highest risk of injury mortality, and by identifying patterns of individual risk within location classes.

Level of Evidence: Level III, Prognostic and Epidemiological

Keywords: Access to care, disparities, geography

INTRODUCTION

The geographic distribution of trauma centers relative to injury incident locations determines both the medical care an individual patient receives following injury, and their exposure to trauma center-based injury prevention programs. Under the current system of trauma care regionalization in the United States (US),[1,2] 90% of the population has timely access to Level I or II trauma center services.[3,4] Unfortunately, rural communities, low income populations, and historically underrepresented minority groups are over represented among the 10% of the population without access to trauma center services.[3-7] These disparities in access to trauma center services represent one of the greatest limitations of the US emergency medical care system,[8] and may contribute to disparities in injury outcomes.[9-13]

Efforts to expand access to trauma center services typically treat distance as a proxy for prehospital travel time, and locations with estimated travel times under one hour are considered to have access to trauma care.[3] Recent studies indicate an effect of trauma center distance independent of prehospital time[14,15] and substantial geographic variation in emergency medical service (EMS) arrival times,[16] suggesting estimated travel times from scene to hospital are not a sufficient measure of trauma center access or need for services. Based on the relationships between trauma centers and EMS providers in regionalized trauma systems,[17] trauma center characteristics (e.g. trauma center designation, hospital ownership) may contribute to the overall prehospital experience.

Need for trauma center services may vary based on the social context at injury event locations. Most injury incidents in the US occur within 10-miles of the patient's residence,[18] and residential communities tend to cluster by socioeconomic status and race.[19] Urban trauma center catchment areas tend to be geographically compact and heavily influenced by the characteristics of the community surrounding the hospital.[20] These patterns suggest significant variation in the social context at injury incident locations. The social context at injury event locations[14] and at trauma centers[21] may impact outcomes for all patients, regardless of their individual characteristics. Given known disparities in access to trauma center services,[3-7] it is possible that geographic barriers magnify the mortality effect of community-level social measures. Unfortunately, the current approach to trauma system organization does not account for the relationship between social context of injury event locations and need for trauma center services.

This study used data from the Maryland Institute for Emergency Medical Services Systems (MIEMSS) and latent class analyses to develop a profile of spatial characteristics associated with concentrated risk of mortality from traumatic injury, and to examine the role of geographically concentrated risk as a determinant of injury mortality. We hypothesized that injury incident locations would be classifiable based on spatial characteristics, that patient and injury characteristics would vary across injury location classes, and that injury locations classes would be associated with injury mortality.

METHODS

Data Sources, Population, and Setting

This study used data from the 2015 MIEMSS Adult Trauma Registry and associated prehospital records from the MIEMSS eMeds patient care reporting system. Injury records for adult patients (age ≥ 18 years) were eligible for inclusion if the patient was injured in Maryland in 2015, transported by a Maryland-based emergency medical services (EMS) company by ground ambulance or helicopter, and treated at a state designated trauma center. Patients who were not treated at a trauma center but died while under EMS care at the injury scene or in transit were also included. Database linkage, mapping, GIS integration, and multiple imputation for missing data were described in detail in previous work.[14] This study was reviewed and approved by the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health.

Variables

The environmental and community-level variables included in the latent class models were identified through prior analyses.[14] Measures of the built environment included distance to the nearest trauma center, characteristics of the nearest trauma center, and land use. Trauma center distance was measured as the Euclidian distance between the scene of the injury event and the nearest trauma center, and categorized as 0-5-miles, 5-10-miles, 10-15-miles, 15-20 miles, or greater than 20 miles. Hospital type was categorized as private Level I/II, public Level I/II, or private Level III. Land use was categorized as residential, transportation, or other. Measures of the social environment included income and median age at the Zip Code Tabulation Area (ZCTA) level. ZCTA per capita income was categorized as less than $20,000, $20,000-$30,000, $30,000-$40,000, or greater than $40,000. ZCTA median age was categorized as less than 30 years, 30-39 years, or 40 of more years. Value ranges for distance, income, and age categories were identified based on visual examination of the distribution of continuous measures. Individual level variables used in the adjusted regression model included age, sex, race and/or ethnicity, injury severity (based on Injury Severity Score and Revised Trauma Score), injury mechanism, Charlson Comorbidity Index, insurance status, and prehospital time, as previously described.[14]

Analytic Approach

Latent class analyses attempt to identify unmeasured classes within a set of observations based on patterns of measured covariates, and to estimate conditional probabilities of class membership, or the probability of a specific trait or measurement given membership in a specific class. Conditional probabilities can then be used to calculate posterior probabilities, that is, the probability that an individual observation belongs to a specific class given the measured traits. Stata 13 (StataCorp, College Station, TX) was used for all statistical analyses. Latent class models were developed and tested using the LCA Stata Plugin developed by Lanza, et al.[22]

In this study, latent class analyses were used to identify patterns of injury scene characteristics indicating different location classes. Using complete case data, latent class models were tested with class counts ranging from two to thirteen. Models were assessed based on standard log-likelihood criteria (e.g. Akaike and Bayesian information criteria[23]), entropy, and visual examination of quantile-quantile plots of the standardized residuals for each model, as described by Wang, et al.[24] Together, these criteria were used to identify the point at which inclusion of additional classes no longer improved model fit.

After identifying the best fitting, most parsimonious model, the latent class model was applied to each imputed data set and results were pooled using the guidelines for multiple imputation proposed by Rubin, et al.[25] The probability of mortality for each class and conditional probabilities of class membership for each location feature were examined, and posterior probabilities were used to assign each pattern of location features to the most likely latent class.

Using ArcGIS Desktop version 10.2.2 (ESRI, Redlands, CA), a grid with quarter mile squares was overlaid on a map of Maryland, and latent classes were applied to each square based on the observed pattern of geographic characteristics within the square. Qualitative class labels were developed based on conditional probabilities of class membership, visual assessment of the geographic distribution of location classes, and comparison of the location class map with the American Communities Project[26] classification of counties in Maryland.

Distribution of individual characteristics were estimated for each class and logistic regression models were used to examine class membership as a determinant of mortality with and without adjustment for individual characteristics. Distributions and regression models were estimated separately for each imputed data set and pooled according to Rubin's guidelines.[25] Standard spatial statistics methods were used to assess residual spatial dependence of the regression models,[27] including semivariograms of the standardized residuals at the individual location level and Moran's I at the ZCTA level.

Sensitivity analyses were used to assess the impact of historic events on injury mortality patterns during the study period. Baltimore City experienced a period of civil unrest in April 2015, which may have impacted EMS response and injury outcomes. To examine the possible effect of the unrest, we performed regression analyses on a subsample of injury incidents excluding locations in Baltimore City. We also compared the periods before and after the unrest using subsamples for March through January 2015 (before) and May through December 2015 (after).

RESULTS

Latent Class Analysis

The study population included 16,082 trauma patients. Most patients were White (52.4%), male (65.8%), younger than age 65 (77.0%), and had blunt injuries (81.9%). Detailed descriptions of the study population and the geographic distribution of injury incidence were previously published.[14] The distribution of model fit statistics and quantile-quantile plots of the residuals indicated that the eight class model was the best fitting, most parsimonious model.[28] Conditional probabilities and prevalence of class membership are available as online supplemental material (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/B97). The distribution of fatal and nonfatal injuries by location class is illustrated in Figure 1. The geographic distribution of location classes is illustrated in Figure 2. Class 1 locations (3.0%) were labeled as rural, and were most likely at non-residential locations more than 10-miles from a Level III trauma center, in communities with per capita income less than $30,000 and median age greater than 40 years. Class 2 locations (11.2%) were labeled as young suburbs, and were most likely between 5 and 15-miles from a Level I/II trauma center, in communities with per capita income greater than $30,000 and median age between 30 and 40 years. Class 3 locations (9.7%) were labeled as aging suburbs, with locations most likely more than 15-miles from a Level I/II trauma center, in communities with per capita income greater than $40,000 and median age greater than 40 years. Class 4 (10.4%) locations were labeled as low income urban core, and locations were most likely within 5-miles of a Level I/II trauma center, in communities with per capita income less than $20,000 and median age between 30 and 40 years. Class 5 (16.8%) locations, labeled as exurban, were most likely more than 5-miles from the nearest trauma center regardless of designation, and in communities with per capita income between $30,000 and $40,000, and median age greater than 40 years. Class 6 (15.7%) locations were labeled as high income urban core, and locations were most likely within 5-miles of a publicly-owned Level I/II trauma center, and in communities with per capita income between $20,000 and $30,000. Class 7 locations (18.4%) were labeled as urban fringe, and were most likely within 5-miles of a privately-owned Level I/II trauma center, and in communities with per capita income between $20,000 and $30,000. Finally, Class 8 locations (14.8%) were labeled as inner suburbs, and were most likely within 10-miles of a Level I/II trauma center, and in communities with per capita income greater than $30,000.

Individual Characteristics

The estimated distributions of individual patient demographic, health, and injury characteristics by location class are presented in Table 1. The case fatality rate was lowest for inner suburb locations (7.0%), and highest for rural (11.6%) and low income urban core (12.9%) locations. Patients injured at low income and high income urban core locations were younger (63.7% and 57.8% younger than 44 years, respectively), more likely to be male (75.3% and 71.7%, respectively), and more likely to be African American (75.7% and 57.5%, respectively) compared to other classes, while exurban, rural, and aging suburb locations had a higher proportion of White/Non-Hispanic injury patients (79.7%, 74.8%, and 65.5%, respectively). Injuries at aging suburb and exurban locations were typically blunt (91.4% and 90.8%, respectively) while low income urban core, high income urban core, and urban fringe locations had the highest incidence of penetrating injury (35.0%, 17.8%, and 13.6%, respectively). People injured at low income urban core locations were least likely to have diagnosed comorbidities (3.0%), while those injured at rural and urban fringe locations were most likely to have comorbidities (9.3% and 6.9%, respectively). Private insurance coverage was highest for rural patients (56.3%), and lowest for low income urban core patients (22.7%). Public insurance and uninsurance rates were highest for high income urban core (44.5% public insurance, 26.2% uninsured) and low income urban core locations (49.7% public insurance, 27.6% uninsured). Mean prehospital time was shortest for low and high income urban core locations (45.1 minutes and 59.2 minutes, respectively), and longest for aging suburb (78.3 minutes) and exurban locations (91.8 minutes).

Mortality Effects

Figure 3 illustrates the estimated odds ratios (OR) and confidence intervals (CI) from logistic regression of latent class membership on mortality, with and without adjustment for individual patient characteristics. The inner suburb class had the lowest odds of death and was used as the reference for both regression models. In the unadjusted model, odds of death for patients injured at low income urban core locations were nearly twice that of patients injured at inner suburb locations (OR = 1.98, 95% CI: 1.56, 2.51) and odds of death for patients injured at rural locations were 75% greater than those injured at inner suburb locations (OR = 1.75, 95% CI: 1.24, 2.48). After adjustment for individual age, sex, race and/or ethnicity, insurance status, Charlson Comorbidity Index, injury mechanism, prehospital time, and mechanism/time interaction, rural location odds of death were nearly twice that of inner suburb locations (OR = 1.98, 95% CI: 1.36, 2.88), while odds of death were 57% higher for young suburb locations (OR = 1.57, 95% CI: 1.14, 2.17), 36% higher for aging suburb locations (OR = 1.36, 95% CI: 1.04, 1.78), and 38% higher for low income urban core locations (OR = 1.38, 95% CI: 1.04, 1.83).

Sensitivity Analyses

Results of the sensitivity analyses are presented in Table 2. The most prevalent location classes observed in Baltimore City were low income urban core (36.3%), high income urban core (22.9%), urban fringe (26.7%), and inner suburb (10.2%). When Baltimore City locations were excluded from the analyses, the unadjusted and adjusted odds ratios for low income urban core location, compared to inner suburb, increased to 7.85 (95% CI: 4.94, 12.48) and 4.19 (95% CI: 2.20, 7.99), respectively. When the analyses were limited to incidents occurring between January and March, the unadjusted effect of low income urban core class was comparable to the effect observed in the total sample (OR = 2.33, 95% CI: 1.13, 4.80). The adjusted effect of low income urban class during the January-March period was comparable to the effect observed in the total sample (OR = 1.33, 95% CI: 0.45, 3.89), but was not statistically significant, likely due to sample size in the three-month period. For the May-December period, the effect of low income urban core was comparable to the effects observed for the total sample (unadjusted OR = 1.91, 95% CI: 1.48, 2.47; adjusted OR = 1.47, 95% CI: 1.03, 2.09).

DISCUSSION

The results of this study suggest that regions with high risk of injury mortality can be identified based on clustering of features of the built and social environments at the injury scene, including trauma center distance and characteristics, land use, community income, and population age. While prior studies examined the built environment and community-level social measures as distinct determinants of injury mortality,[3,9,12-14,21] this is the first study to identify patterns of clustering based on incident location characteristics, and to examine location classes as determinants of mortality. Eight distinct classes of injury location were identified in Maryland with variable case fatality rates and distributions of demographic, health, and injury characteristics. Inner suburb locations, marked by high ZCTA income and proximity to Level I/II trauma centers, had the lowest estimated odds of death in both the adjusted and unadjusted regression models while rural, suburban, and low income urban locations had the highest odds of death. The urban and rural location classes identified in this study are consistent with existing classification of geography in the US. The number of suburban classes identified, combined with variation in risk factors and outcomes across these classes, indicates greater geographic variation in injury risk than generally assumed. In addition to identification of previously unclassified location types, the methods used in this study provide an empirical basis for resource allocation, and serve as an important check against implicit bias in our assessment of community-level risk of injury and need for intervention.

Rural, young suburban, aging suburban, and exurban locations all appeared to have some distance-based barriers to trauma center services. Rural locations had the second highest case fatality rate, and the highest odds of death after adjustment for individual characteristics. Estimated odds of death for rural locations increased following adjustment, suggesting that individual characteristics mask some of the risk associated with the location class. This is most likely explained by the low proportion of rural incidents with penetrating injuries, as well as the relatively large proportion of patients with private insurance, despite the low median income associated with class membership. Odds of death for young suburb and aging suburb locations were not significantly different than those for inner suburbs in the unadjusted model, but odds of death for both increased considerably after adjustment for individual characteristics. The effects of both suburb classes were likely masked by low incidence of penetrating injury and high rates of private insurance enrollment, while higher proportions of female and White patients further masked the effect of aging suburb locations. Odds of death were similar for exurban and inner suburb locations despite longer trauma center distances and potential barriers to trauma center services at exurban locations. Individuals injured at exurban locations were more likely to be

White, have private insurance, and have blunt injuries, which are all associated with reduced injury mortality risk,[29,30] and may mitigate the effect of distance and prehospital time.

Trauma center distances were shortest for urban and inner suburb locations. High income urban core and urban fringe locations were among the lowest risk classes identified based on case fatality rate and adjusted estimates of mortality odds, and were not significantly different than inner suburb locations in terms of mortality. Compared to inner suburb locations, high income urban core and urban fringe locations had higher proportions of critical and penetrating injuries; however, the mortality risk associated with the injury characteristics appears to be mitigated by shorter prehospital times, consistent with the relationship between injury mechanism, prehospital time, and mortality demonstrated in the literature.[14,29,30] Low income urban core locations had the highest case fatality rate of all location classes, but the estimated odds of death decreased substantially after adjustment for individual characteristics, suggesting high proportions of individual characteristics associated with increased mortality (e.g. African American race, male sex, penetrating injury[29-32]) confounded the relationship between location class and odds of death. While adjustment for individual characteristics significantly reduced the effect of low income urban core locations, it was the only urban location class with estimated odds of death significantly greater than inner suburb locations.

Based on the observed patterns in mortality and individual characteristics, location class assignments may be useful when tailoring primary prevention and injury response interventions. For example, odds of death at low income urban core locations were elevated despite proximity of Level I/II trauma centers. Low income urban core locations had high incidence of penetrating injury, suggesting low income urban core locations should be priority targets for violence prevention interventions, community-based training for bystander first aid (such as the American

College of Surgeons Stop the Bleed campaign[33]), and enhanced EMS efforts tailored to treatment of penetrating injuries.

Rural locations were characterized primarily by lack of access to trauma care, with locations in the class generally more than 10-miles from a Level III trauma center. While individuals injured at rural locations had low incidence of penetrating injury and high rates of private insurance coverage, odds of death for rural injury incidents were among the highest observed, potentially due to extended EMS response times.[16] This suggests that rural locations would benefit from primary prevention interventions to reduce blunt injuries, as well as bystander first aid training and EMS efforts to support patients with blunt injuries during prolonged prehospital intervals. Trauma centers serving these communities should work closely with prehospital providers and critical access hospitals to implement injury prevention programs and EMS care that respond to the unique needs of rural populations. These concepts align with suggestions from the National Academies of Medicine report "A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury," which emphasizes the importance of the trauma care continuum, including the high quality prehospital care.[34]

Limitations

The unique structure of trauma system services[35] and the geographic distribution of social and environmental factors related to injury mortality in Maryland limit the generalizability of this study to other settings; however, it may be possible to validate these findings for other states and regions using publicly available data. With limits of generalizability in mind, the results of this study are useful as a starting point for inquiry into the use of spatially defined data as predictors of injury mortality at the population level.

There are concerns for internal and external validity of this study due to historic events during the study period. The study population included injury patients from Baltimore City during and after a period of civil unrest in the spring of 2015, and a subsequent rise in homicide incidence.[36] There is considerable overlap between the low income urban core class identified in this analysis and the neighborhoods most impacted by the unrest and increased homicide rate. It is possible that safety concerns for first responders, residual unrest, or other unmeasured factors impacted the delivery of care and injury outcomes in these areas. Low income urban core locations were observed in regions of the state not impacted by civil unrest, and the effect of low income urban core location increased when Baltimore City locations were excluded from analyses, indicating that historic events did not increase the mortality effect associated with low income urban core locations, mitigating concerns regarding internal validity. The unadjusted and adjusted effects of low income urban core were similar for the months before and after the period of civil unrest, which suggests the events of April 2015 did not significantly impact geographic patterns of injury outcomes in the state, despite changes in injury incidence. Homicide incidence rates in Baltimore City have remained elevated in the months following the 2015 unrest,[36] supporting the continued relevance of these results for short term practice and policy, despite potential limitations for long term generalizability of the mortality risk attributed to low income urban core locations.

Finally, this study was limited to injury patients transported to trauma centers by EMS, did not include patients transported by private vehicle, those transported to non-trauma centers without transfer to a trauma center, or those who died at the injury scene before EMS arrival. Private vehicle transport is most common among patients with penetrating trauma injured at urban locations,[37] while injury deaths at non-trauma centers or prior to EMS arrival at the incident scene are most likely to occur among patients with critical injuries and/or significant barriers to trauma care. Exclusion of these patients may attenuate our results towards the null.

Conclusion

This study indicates that clusters of spatially defined risk factors for injury mortality are identifiable using latent class analyses, and that the population injury patients varies across location classes. Regression analyses suggest the protective benefit of some location classes may compensate for the effect of individual patient characteristics, while the same individual patient characteristics may mask the effect of location in other regions. The results of this study may be useful for planning and implementation of prevention and treatment efforts, including targeted efforts to reduce injury incidence, and identification of regions in need of additional prehospital or trauma center resources.

Public health practitioners at the state and local levels may be able to supplement the models used in this study with additional data not available to researchers to support nuanced tailoring of prevention and treatment efforts. Researchers should attempt to replicate this study in other regions, both to enhance our understanding of geographic concentration of injury risk factors, and to identify additional environmental and social factors that may improve our ability to identify regions with elevated injury mortality risk. Policymakers and practitioners should consider community level measures of income and age when making decisions regarding the allocation and designation of trauma centers.

Author Contributions

Molly Jarman conceived of this study, completed the analysis, led interpretation of the study results, and led the writing. Renan Castillo contributed to the study design, supervised the analysis and interpretation of study results, and assisted with writing. Frank Curriero contributed to the study design, interpretation of results, and writing. Elliott Haut assisted with interpretation of the study results and with writing.

Acknowledgements

This study was supported by an Agency for Healthcare Research Quality training grant (T32HS000029) and by the Johns Hopkins Center for Injury Research and Policy (William Haddon Jr. Fellowship).

We thank Dr. William Thompson, John New, Shanae Williams, Tefferra Alemayehu, and the Maryland Institute for Emergency Medical Services Systems for their support of the project.

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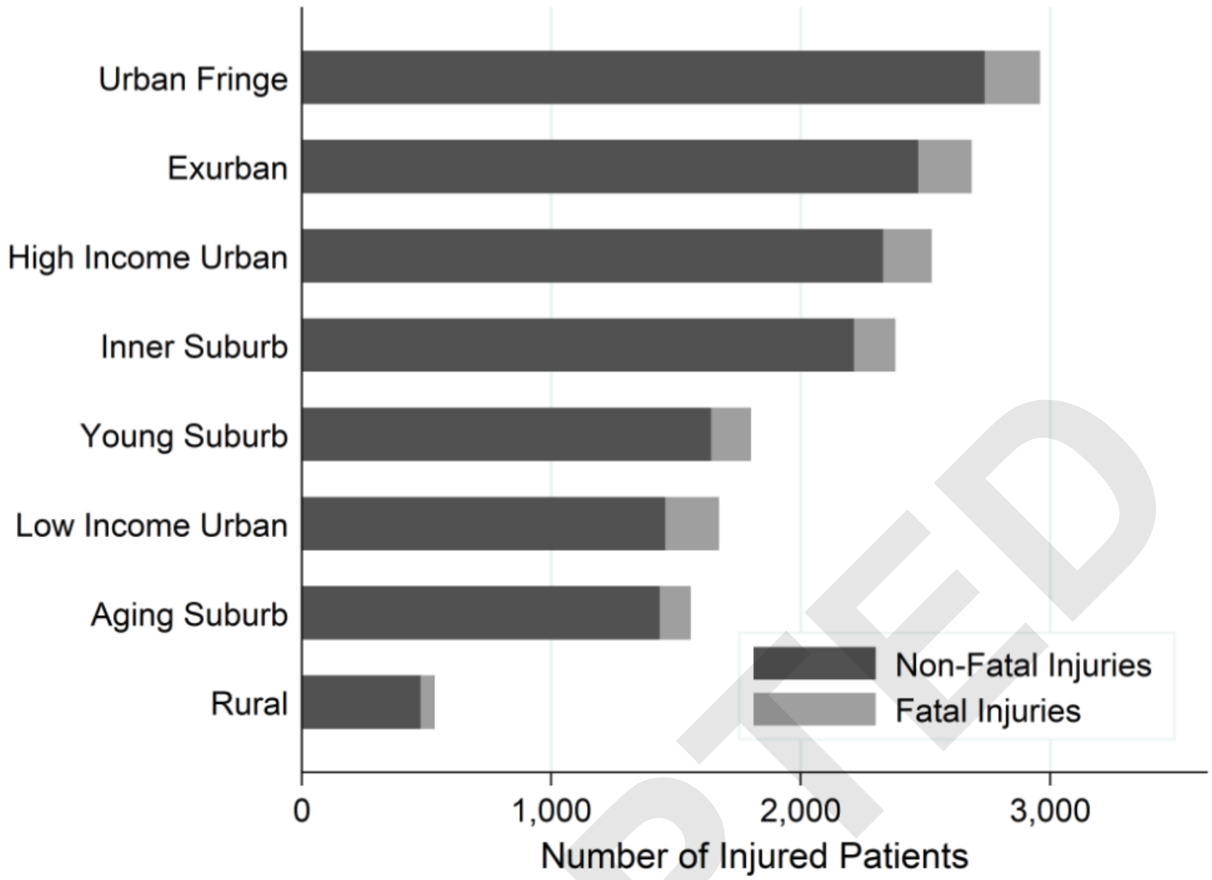
Figure 1: Distribution of Fatal and Nonfatal Injuries by Location Class

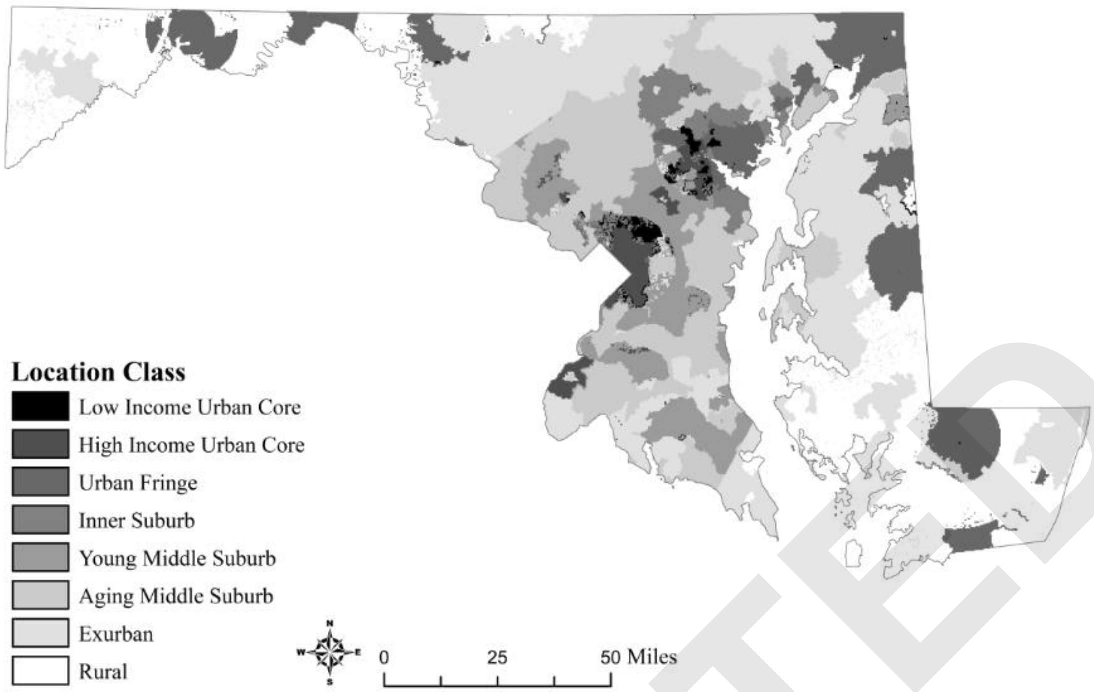
Figure 2: Geographic Distribution of Latent Classes of Injury Events in Maryland, 2015

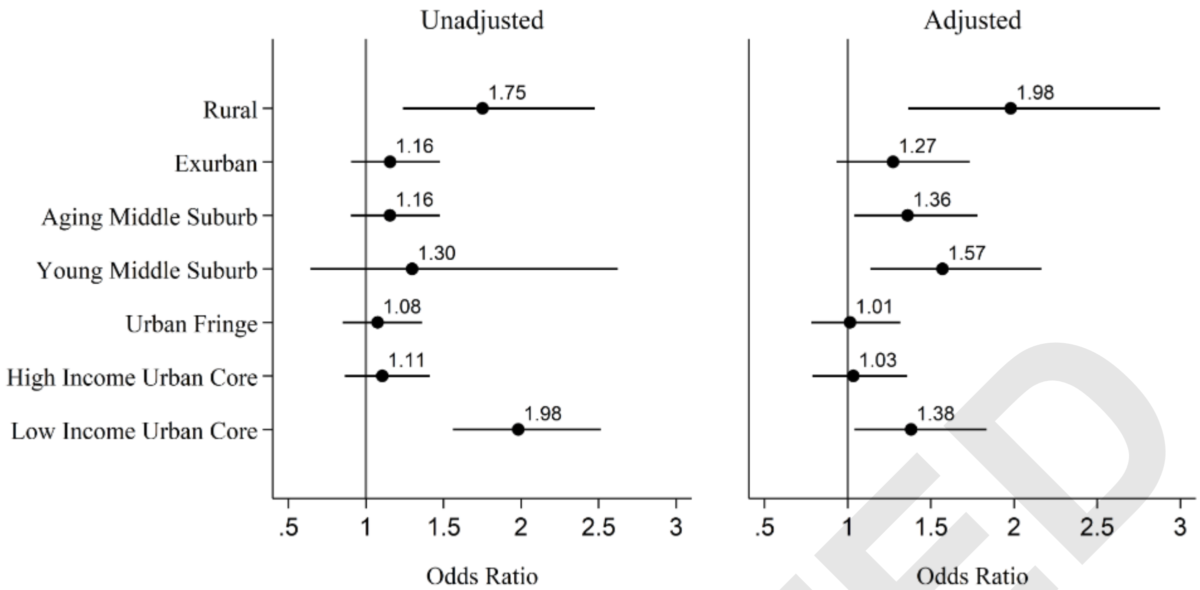
Figure 3: Mortality Odds Ratios by Location Class for Injury Events in Maryland, 2015

Caption: Inner Suburb is the reference class for odds ratios. Adjusted model included age, sex, race/ethnicity, insurance status, Charlson Comorbidity Index, severity, mechanism, prehospital time, and mechanism/time interaction.



Urban Fringe
Exurban
High Income Urban
Inner Suburb
Young Suburb
Low Income Urban
Aging Suburb
Rural
Non-Fatal Injuries
Fatal Injuries
0
1,000
2,000
3,000
Number of Injured Patients


Location Class
Low Income Urban Core
High Income Urban Core
Urban Fringe
Inner Suburb
Young Middle Suburb
Aging Middle Suburb
Exurban
Rural
0
25
50 Miles



Unadjusted
Adjusted
Rural
Exurban
Aging Middle Suburb
Young Middle Suburb
Urban Fringe
High Income Urban Core
Low Income Urban Core
1.75
1.16
1.16
1.30
1.08
1.11
1.98
1.98
1.27
1.36
1.57
1.01
1.03
1.38
.5
1
1.5
2
2.5
3
Odds Ratio

TABLES AND FIGURES

Table 1: Estimated[a] Distribution of Individual Characteristics by Location Class of Injury Incidents in Maryland, 2015

	Rural	Young Suburb	Aging Suburb	Low Income Urban	Exurban	High Income Urban	Urban Fringe	Inner Suburbs
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Died								
No	88.4 (85.5, 91.3)	91.1 (89.4, 92.9)	92.0 (90.8, 93.2)	87.1 (85.4, 88.8)	92.0 (90.8, 93.2)	92.4 (91.3, 93.4)	92.5 (91.6, 93.5)	93.0 (91.8, 94.3)
Yes	11.6 (8.7, 14.5)	8.9 (7.1, 10.7)	8.0 (6.8, 9.2)	12.9 (11.3, 14.6)	8.0 (6.8, 9.2)	7.7 (6.6, 8.7)	7.5 (6.6, 8.4)	7.0 (5.7, 8.2)
Age								
18-24	16.4 (13.0, 19.9)	16.6 (14.6, 18.5)	12.2 (10.7, 13.7)	19.7 (17.7, 21.7)	14.0 (12.4, 15.6)	17.0 (15.5, 18.5)	15.3 (14.0, 16.6)	15.2 (13.5, 16.9)
25-34	19.7 (15.9, 23.6)	20.1 (17.4, 22.8)	15.3 (13.6, 16.9)	29.0 (26.7, 31.3)	16.1 (14.4, 17.8)	25.1 (23.4, 26.8)	20.3 (18.9, 21.7)	18.7 16.3, 21.2)
35-44	13.1 (10.1, 16.1)	15.3 (13.6, 17.0)	11.9 (10.5, 13.3)	15.0 (13.2, 16.8)	10.6 (9.2, 11.9)	15.7 (14.1, 17.2)	12.2 (10.9, 13.4)	13.0 (11.4, 14.5)
45-54	13.8 (10.7, 17.0)	14.6 (12.7, 16.4)	14.1 (12.5, 15.7)	14.7 (12.9, 16.5)	13.8 (12.2, 15.4)	14.4 (12.9, 15.87)	15.7 (14.4, 17.1)	13.0 (11.5, 14.6)
55-64	14.1 (10.5, 17.8)	13.2 (11.4, 14.9)	14.9 (13.3, 16.5)	11.5 (9.9, 13.1)	15.3 (13.6, 16.9)	12.8 (11.5, 14.2)	13.5 (12.3, 14.7)	11.4 (9.7, 13.0)
65-74	10.8 (7.7, 13.9)	7.8 (6.4, 9.2)	12.4 (10.9, 13.9)	4.7 (3.6, 5.8)	10.4 (8.9, 11.8)	6.8 (5.8, 7.8)	8.2 (7.2, 9.2)	8.8 (7.3, 10.4)
75+	12.0 (8.7, 15.3)	12.5 (10.7, 14.3)	19.3 (17.5, 21.1)	5.4 (4.2, 6.6)	19.9 (18.2, 21.7)	8.2 (7.1, 9.3)	14.9 (13.6, 16.2)	19.9 (17.4, 22.5)
Sex								
Male	63.7 (59.3, 68.2)	65.3 (62.8, 67.7)	62.4 (60.2, 64.5)	75.3 (73.1, 77.5)	60.1 (57.9, 62.4)	71.7 (69.9, 73.4)	64.9 (63.1, 66.6)	63.1 (60.5, 65.8)
Female	36.3 (31.8, 40.7)	34.8 (32.3, 37.2)	37.6 (35.5, 39.8)	24.7 (22.5, 26.9)	39.9 (37.6, 42.1)	28.3 (26.6, 30.1)	35.1 (33.4, 36.9)	36.9 (34.2, 39.5)
Race/Ethnicity								
White	74.8 (70.9, 78.7)	45.1 (39.9, 50.2)	65.5 (63.0, 68.0)	18.8 (16.8, 20.8)	79.7 (77.5, 81.9)	27.4 (25.6, 29.3)	60.0 (58.1, 61.8)	56.3 (50.9, 61.8)
African American	18.4 (14.8, 22.0)	37.1 (33.5, 40.7)	20.1 (18.2, 22.0)	75.7 (73.5, 77.9)	12.7 (11.0, 14.5)	57.5 (55.5, 59.5)	32.1 (30.3, 33.9)	31.3 (27.8, 34.7)
Hispanic	4.0 (2.2, 5.9)	9.8 (7.3, 12.2)	7.0 (5.7, 8.2)	2.4 (1.6, 3.2)	3.0 (2.2, 3.8)	9.7 (8.5, 10.9)	4.2 (3.4, 4.9)	6.5 (4.2, 8.7)
Other	2.8 (1.1, 4.5)	8.1 (6.6, 9.5)	7.5 (6.2, 8.7)	3.1 (2.3, 4.0)	4.6 (3.4, 5.7)	5.4 (4.4, 6.4)	3.8 (3.0, 4.5)	6.0 (4.7, 7.2)
Injury Severity[b]								
Mild	89.9 (87.1, 92.6)	90.7 (88.9, 92.5)	90.7 (89.2, 92.2)	89.6 (88.0, 91.2)	90.8 (89.1, 92.6)	91.8 (90.6, 93.0)	90.5 (89.0, 92.0)	91.3 (89.7, 93.0)
Moderate	4.2 (2.3, 6.1)	4.2 (3.1, 5.2)	4.4 (3.4, 5.4)	3.0 (1.5, 4.5)	3.6 (2.6, 4.5)	3.4 (2.6, 4.1)	3.7 (2.9, 4.5)	3.2 (2.3, 4.1)
Severe	4.9 (2.8, 6.9)	4.4 (3.3, 5.6)	4.2 (3.1, 5.2)	4.9 (3.8, 6.1)	4.6 (3.5, 5.8)	3.7 (2.6, 4.7)	4.6 (3.5, 5.7)	4.6 (3.4, 5.8)
Critical	1.1 (0.1, 2.0)	0.8 (0.2, 1.3)	0.8 (0.4, 1.2)	2.5 (1.0, 3.9)	1.0 (0.0, 2.3)	1.2 (0.7, 1.7)	1.2 (0.8, 1.7)	0.9 (0.3, 1.4)

Injury Mechanism								
Blunt	86.9 (83.9, 90.0)	86.8 (84.9, 88.6)	91.4 (90.0, 92.8)	59.6 (57.1, 62.0)	90.8 (89.4, 92.1)	76.9 (75.2, 78.5)	80.1 (78.6, 81.6)	84.1 (82.3, 85.8)
Penetrating	7.2 (4.8, 9.7)	7.4 (5.9, 9.0)	4.9 (3.8, 6.0)	35.0 (32.6, 37.4)	5.1 (4.1, 6.1)	17.8 (16.3, 19.3)	13.6 (12.4, 14.9)	10.7 (9.2, 12.1)
Both	1.5 (0.4, 2.6)	2.4 (1.6, 3.1)	1.3 (0.8, 1.9)	3.2 (2.3, 4.1)	1.7 (1.1, 2.3)	2.3 (1.7, 2.8)	3.5 (2.9, 4.1)	2.5 (1.8, 3.2)
Other	4.3 (2.5, 6.2)	3.4 (2.5, 4.4)	2.4 (1.7, 3.1)	2.3 (1.5, 3.0)	2.5 (1.8, 3.2)	3.1 (2.4, 3.8)	2.8 (2.2, 3.4)	2.8 (2.0, 3.5)
Charlson Index								
0	90.7 (87.9, 93.5)	95.2 (94.1, 96.4)	95.1 (94.1, 96.2)	97.1 (96.2, 97.9)	93.3 (92.2, 94.5)	95.8 (95.0, 93.1)	93.1 (92.2, 94.0)	95.2 (94.2, 96.2)
1-4	9.1 (6.3, 11.8)	4.3 (3.2, 5.4)	4.3 (3.3, 5.3)	2.6 (1.8, 3.4)	5.9 (4.8, 7.0)	3.7 (3.0, 4.5)	6.7 (5.8, 7.6)	4.7 (3.7, 5.6)
5+	0.2 (0.0, 0.7)	0.5 (0.1, 0.8)	0.6 (0.2, 0.9)	0.4 (0.1, 0.7)	0.8 (0.4, 1.2)	0.5 (0.2, 0.8)	0.2 (0.0, 0.4)	0.2 (0.0, 0.4)
Insurance Status								
Private	56.3 (51.4, 61.1)	44.1 (41.4, 46.7)	48.8 (46.3, 51.3)	22.7 (20.4, 25.0)	45.9 (43.1, 48.8)	29.4 (27.5, 31.2)	38.3 (36.4, 40.3)	43.3 (41.1, 45.6)
Public	33.3 (28.3, 38.4)	34.9 (31.8, 38.0)	37.2 (34.2, 40.2)	49.7 (47.0, 52.5)	41.5 (39.0, 44.0)	44.5 (42.3, 46.6)	40.5 (38.7, 42.4)	36.2 (33.9, 38.6)
None	10.4 (7.0, 13.8)	21.0 (18.5, 23.5)	14.0 (12.2, 15.9)	27.6 (24.9, 30.2)	12.6 (11.0, 14.3)	26.2 (24.2, 28.2)	21.1 (19.6, 22.7)	20.5 (18.3, 22.7)
Prehospital time	68.7 (62.0, 75.4)	66.9 (62.4, 71.4)	78.3 (73.3, 83.4)	45.1 (42.6, 47.5)	91.8 (86.0, 97.6)	59.2 (56.1, 62.2)	54.1 (51.7, 56.6)	61.5 (58.7, 64.4)

[a]Estimated distributions based on multiple imputation

[b]Injury severity based on Injury Severity Score (ISS) and unweighted Revised Trauma Score (RTS). RTS was used only when ISS was not available. Mild injury includes ISS 1-9 and RTS 12. Moderate injury includes ISS 10-15 and RTS 11. Severe injury includes ISS 16-24 and RTS 4-10. Critical injury includes ISS $\geq$ 25 and RTS $\leq$ 3.

Table 2: Sensitivity Analyses for Odds of Injury Mortality in Maryland, 2015						
	Unadjusted			Adjusted		
	Odds Ratio	95% CI	*p*	Odds Ratio	95% CI	*p*
Excluding Baltimore City						
Low Income Urban	7.85	4.94, 12.48	< 0.001	4.19	2.20, 7.99	< 0.001
High Income Urban	1.05	0.79, 1.38	0.742	1.07	0.74, 1.55	0.711
Urban Fringe	0.99	0.76, 1.30	0.978	0.88	0.88, 0.52	0.657
January-March Only[a]						
Low Income Urban	2.33	1.13, 4.80	0.031	1.33	0.45, 3.89	0.613
High Income Urban	0.97	0.49, 1.92	0.926	0.95	0.36, 2.49	0.919
Urban Fringe	0.96	0.49, 1.87	0.897	0.81	0.33, 1.02	0.654
May-December Only[a]						
Low Income Urban	1.91	1.48, 2.47	< 0.001	1.47	1.03, 2.09	0.044
High Income Urban	1.10	0.84, 1.44	0.493	1.19	0.83, 1.72	0.355
Urban Fringe	1.04	0.80, 1.34	0.793	0.98	0.56, 1.69	0.930

[a]Effect of urban locations examined for January-March and May-December to assess temporal impact of April 2015 civil unrest in Baltimore City.