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## Safety in Numbers: Are Major Cities the Safest Places in the United States?

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### Abstract

**Study objectives**—Many US cities have experienced population reductions, often blamed on crime and interpersonal injury. Yet the overall injury risk in urban areas compared with suburban and rural areas has not been fully described. We begin to investigate this evidence gap by looking specifically at injury-related mortality risk, determining the risk of all injury death across the rural-urban continuum.

**Methods**—A cross-sectional time-series analysis of US injury deaths from 1999 to 2006 in counties classified according to the rural-urban continuum was conducted. Negative binomial generalized estimating equations and tests for trend were completed. Total injury deaths were the primary comparator, whereas differences by mechanism and age were also explored.

**Results**—A total of 1,295,919 injury deaths in 3,141 US counties were analyzed. Injury mortality increased with increasing rurality. Urban counties demonstrated the lowest death rates, significantly less than rural counties (mean difference=24.0 per 100,000; 95% confidence interval 16.4 to 31.6 per 100,000). After adjustment, the risk of injury death was 1.22 times higher in the most rural counties compared with the most urban (95% confidence interval 1.07 to 1.39).

**Conclusion**—Using total injury death rate as an overall safety metric, US urban counties were safer than their rural counterparts, and injury death risk increased steadily as counties became more rural. Greater emphasis on elevated injury-related mortality risk outside of large cities, attention to locality-specific injury prevention priorities, and an increased focus on matching emergency care needs to emergency care resources are in order.

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## INTRODUCTION

### Background

By 2008, more than half of the world's people was living in urban areas for the first time in human history.<sup>1,2</sup> This growing urbanization of global populations has been called an emerging humanitarian disaster, partly because of prominent urban safety hazards such as injuries.<sup>3</sup> In contrast, during the past few decades the United States has experienced unprecedented reductions in population in many of its largest cities and population centers. The reasons for these reductions include the movement of jobs and housing outside of cities, differences in the quality of public education and municipal services, and levels of crime and blight in many city centers.<sup>4,5</sup> Among these reasons for urban flight in the United States, the perception of crime risk has been perhaps the most publicized and influential.<sup>6,7</sup>

### Importance

From 1999 to 2006, nearly 1.3 million people died of injuries in the United States.<sup>8</sup> Most of these people were younger than 45 years and lived in urban areas.<sup>9</sup> This might be interpreted as suggesting that young urbanites bear the greatest burden of injury related mortality risk in the United States and, by extension, that large US cities are unsafe places to live and work. In addition, previous work on US homicide and crime victimization also supports the notion that injury risk is concentrated in large US cities.<sup>10</sup> However, it is possible that the actual safety risk in urban America is exaggerated and that the true risk experienced by urban inhabitants is lower than commonly perceived.<sup>11</sup> Paradoxically, research also exists suggesting that rural areas bear a disproportionately high level of risk for certain serious injuries such as suicide and motor vehicle injuries, raising the possibility of increased safety threats to rural inhabitants.<sup>10,12</sup>

### Goals of This Investigation

These different points of view urban areas unsafe on the one hand, rural areas unsafe on the other are driven by analyses that focus only on specific types or causes of injuries and by the individual ability to misconceive risk.<sup>13</sup> We seek to remedy this by analyzing injury death rates of all types across all US geographies, from big cities to small towns. Creating a fuller understanding of the injury related mortality risk across the United States can also inform the evaluation of trauma systems, given our understanding of the importance of timely access to trauma care<sup>14</sup> and the difficulty of accessing trauma care in many rural areas.<sup>15–19</sup> In fact, one of the objectives of the Department of Health and Human Services' Health People 2020 initiative is to increase access to trauma care in the United States,<sup>20</sup> and an understanding of where services are needed will inform the implementation of this initiative. In addition, targeted injury prevention has been previously described as a way to increase effectiveness and efficiency of prevention work, and understanding how the risk of injury by mechanism differs across various environments will aid in this effort.<sup>21</sup> Finally, staffing of emergency departments (EDs) is known to vary across the rural urban landscape, with rural hospitals being significantly less likely to be staffed by emergency physicians.<sup>22,23</sup> Understanding the injury mortality distribution across rural areas can help inform the debate over the future and planning of the ED workforce and the emergency care system as a whole. Therefore, to address all of these goals, we will examine the relative risk of injury

death across the rural urban landscape in aggregate, as well as by age and mechanism subtype.

## MATERIALS AND METHODS

### Study Design and Setting

We performed a cross sectional time series analysis of all injury deaths that occurred in the United States during 1999 through 2006. The study was approved by the institutional review board at the University of Pennsylvania.

### Selection of Participants

Decedents were identified through the non public use Multiple Cause of Death data files from the National Vital Statistics System of the National Center for Health Statistics. These data are created through the uniform registration of death certificates and describe all documented deaths in the United States. Codes defined by the *International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10)*<sup>24</sup> were used to extract decedents with injury as the cause of death (V01 Y36, U01 03, Y85 86, 87.1, 87.2, 89.0, 89.1, and 89.9). Deaths with an invalid or missing Federal Information Processing Standards code for county of occurrence (n=7,434) and deaths classified as terrorism (n=2,927) were excluded from this analysis. Injury deaths were further classified by intent (suicide/homicide/unintentional) and mechanism through the use of *ICD-10* external cause codes.<sup>25</sup> Injury mechanisms evaluated were cuts, drowning, falls, fire, firearms, machinery, transportation (including the subset of motor vehicle transport), environmental (flood, animal attack, cold exposure), overexertion, poisoning, struck (hit by object/person/animal), and suffocation (Table E1, available online at <http://www.annemergmed.com>).

### Methods of Measurement

Each decedent was assigned to the US county where injury death occurred according to Federal Information Processing Standards geographic codes, including deaths in counties with fewer than 100,000 persons as per a special data request approved by the National Center for Health Statistics. We chose to use county of occurrence to best describe the injury related mortality risk according to time spent in a given county, allowing a more direct understanding of the results. However, home location has been shown to be an appropriate proxy for injury location, with the majority of injury deaths occurring close to the residence<sup>26</sup>; therefore, it is likely that results would be similar if derived according to county of residence. All 3,141 US counties were included in the analysis, including the District of Columbia as a county equivalent. We identified 2 changes in county boundaries during the study period and adjusted population centroid locations and county assignments accordingly for data years after the changes took effect.<sup>27</sup>

Counties were classified according to a 10 category ordinal variable representing an urban rural continuum (Table E2, available online at <http://www.annemergmed.com>). This variable distinguishes counties by both population size and proximity to metropolitan areas, thus providing different information than would a simple categorization of counties on the

basis of population size, land area, proximity to metropolitan areas, or population density, each as a separate variable. Our 10 category variable is based on the 9 category urban rural continuum codes from the US Department of Agriculture, with an additional category to distinguish counties with a population of 1 million or greater as these distinct “nuclear” counties with potential to have increased risk of deaths from injuries.<sup>28–30</sup> This 10 category classification scheme has been used in multiple previous geographic studies and is validated by the US Department of Agriculture according to census data.<sup>28,31</sup>

County specific rates of death were calculated and associated population data were used to derive variables hypothesized to affect the occurrence of injury related deaths, which were chosen a priori; specifically, county specific median age; median per capita income; and the proportion of blacks, Hispanics, men, unemployed, households headed by women, individuals living alone, individuals older than 16 years and living alone, individuals living under the poverty line, and adults (aged >18 years) with college education. Region of the country (Northeast, Midwest, South, and West) was also used to account for spatial heterogeneity. Each of these variables was obtained from the Area Resource File<sup>32</sup> and the 2000 US Census Bureau.<sup>33</sup> There were no counties with missing demographic data. County measures of total population were based on annual census estimates, and specific age subgroup total populations were calculated by projecting the 2000 Census age proportions onto the annual population estimates.

## Outcome Measures

The outcome variable analyzed was injury death rate overall, as well as by cause and intent. Rates of death in each of these groupings were analyzed at the level of the county.

## Primary Data Analysis

We examined variations in county specific rates of death across the 10 classes of the urban rural continuum, with most urban counties treated as the reference group, after controlling for confounding factors (above). We used general estimating equations (GEEs) to appropriately account for longitudinal correlation arising from collecting data on the same counties over time. We chose to use a negative binomial link function<sup>34</sup> rather than the Poisson distribution to account for overdispersion in the count data.<sup>35</sup> The robust variance estimator was used to account for longitudinal correlation, and the model included an offset for total population and scale parameter  $\Phi$ . Alternatively, a mixed effects model approach that included county level random effects could have been used. We preferred a GEE approach for 2 main reasons. First, mixed effects models rely on the assumption that the random effects are correctly specified, whereas the GEE approach is reliable even if the correlation structure is incorrectly specified.<sup>36</sup> Second, GEE generates direct inference for the population of US citizens as opposed to the mixed effects model’s direct inference to the population of US counties.<sup>37</sup>

Excessively collinear independent variables were determined by using variance inflation factor analysis and limiting the final models to the set of independent variables with variance inflation factor less than 5.<sup>38,39</sup> Analyses were run for each dependent variable as unadjusted models, as full models adjusting for all possible (but noncollinear) covariates,

and as reduced models. Reduced models were created with the quasi likelihood under independence model criterion to determine the model with the best fit for each dependent variable compared with the unadjusted model, with each variable being added as an individual covariate to the model testing the association between rural urban status of the county and injury death rates to test each covariate's importance to the model.<sup>40</sup> Subsequently, all variables found to be important in this individual analysis were included in a larger reduced model, which was further refined by testing against models created by eliminating each variable individually to determine covariates that, though important to the model individually, lose their importance when other covariates are added. Once unimportant covariates were removed, we determined the final model to be the reduced model with best fit. Tests for linear trend were performed by modeling the urban rural continuum variable as continuous. Given differences in typical injury mechanisms, typical geographic location of injury occurrence, and physiologic response to injury by age, we also subdivided our analysis into 5 age categories, using census cut points ( < 14 years, 15 to 19 years, 20 to 44 years, 45 to 64 years, and ≥ 65 years). To explore modification of the association between risk of injury death and rural urban nature of the county, we used the total population to test interactions between covariates of interest and rurality. All analyses were completed with Stata/MP 11 software (StataCorp, College Station, TX).

Given our negative binomial model specification, we did not directly adjust for spatial autocorrelation. However, we obtained residuals of our model and tested these for spatial autocorrelation with ArcGIS software (ESRI, Redlands, CA). We ran Moran's I and Geary's c tests on the residual values for each county averaged across the 8 years, using inverse distances between counties. The Geary's c test allows only positive values to be tested and was run with absolute value of the residuals.

Finally, because the robustness of the national trauma system is paramount to the care of injured patients and there are known gaps in trauma center access in rural areas, we generated a variable to test the effect of trauma center proximity on the relationship between injury mortality and county rurality. Using contiguous county data from GreatData (<http://www.greatdata.com>) in conjunction with data from the Trauma Information Exchange Program,<sup>41</sup> we determined the number of accredited Level I and II trauma centers in each county and assigned to each county the total number of trauma centers in it and its neighboring counties as a way to determine the "proximity" to a trauma center for inhabitants of that county. We then added this covariate to our GEE model evaluating the relative rate of injury related mortality by urban rural nature of the county and determined the effect on our result.

## RESULTS

### Characteristics of Study Subjects

Our analysis included all 3,141 United States counties, in which there were 1,295,919 injury deaths during the period studied (1999 to 2006). The overall injury death rate was 56.2 per 100,000 persons in the population. The overall death rate for unintentional injury was 37.5 per 100,000, and the overall death rate for intentional injury (homicide and suicide) was 17.0 per 100,000. The most common mechanisms for injury death across all subjects were motor

vehicle related, which occurred at a rate of 14.9 per 100,000, and firearm related, which occurred at a rate of 10.4 per 100,000. Demographic characteristics of all counties by rural urban continuum category are described in Table E1 (available online at <http://www.annemergmed.com>). The injury death rate increased slightly during the 8 year period, with a rate ratio of 1.02 (95% confidence interval [CI] 1.01 to 1.02; reference year 1999).

## Main Results

The overall injury death rate increased with increasing rurality (Table 1), and a significant difference between the injury death rate in the most rural compared with the most urban counties was identified (difference of 24.0 per 100,000; 95% CI 16.4 to 31.6 per 100,000). Both unadjusted and adjusted injury death rate ratios were significantly elevated in the most rural counties compared with the most urban (Tables 1 and 2). Tests for linear trends were significant across the modified urban rural continuum in both the unadjusted and adjusted models (Table 1). Significantly elevated risks of injury death in the most rural counties (compared with the most urban) were found in all age groups younger than 45 years (Table 1). Figure 1 graphically displays the urban rural continuum categories, population density, and all injury death rates for US counties. Visually, inverse trends exist between rurality and injury death rate.

Unintentional injury death rates in US counties varied significantly as a function of rurality, with higher death rates in the most rural [modified rural urban continuum category 9 (mruc9)] compared with the most urban [modified rural urban continuum category 0 (mruc0)] counties [rate ratio (RR) 1.42; 95%CI 1.23 to 1.65]. The suicide injury death rate also showed some increase with increasing rurality, but the difference between the most rural and most urban counties did not reach significance (Figure 2; Table 2). On the other hand, the homicide death rate decreased as counties became more rural (RR 0.44; 95% CI 0.37 to 0.53) (Table 2).

Trends were similar among age subgroups. Increases in unintentional injury death from the most urban to the most rural counties were observed, and differences were found to be significant in all fully adjusted models for all age subgroups (RRs [mruc9 counties compared with mruc0 counties]: 0 to 14 years [1.32, 1.07 to 1.61], 15 to 19 years [1.68, 1.42 to 1.99], 20 to 44 years [1.54, 1.31 to 1.81], 45 to 64 years [1.25, 1.08 to 1.45], and 65 years [1.20, 1.01 to 1.41]). For suicides, the general trend of increase in raw suicide death rates in more rural areas continued; however, this difference reached significance only in the fully adjusted models for the youngest 2 age groups (RRs [mruc9 counties compared with mruc0 counties]: 0 to 14 years [2.47, 1.64 to 3.71] and 15 to 19 years [1.68, 1.33 to 2.13]). For homicide, a trend of decreased homicide death in more rural areas was observed and was significant in full year adjusted models for all age subgroups except for older adults (≥ 65 years) (RRs [mruc9 counties compared with mruc0 counties]: 0 to 14 years [0.50, 0.32 to 0.79], 15 to 19 years [0.28, 0.19 to 0.42], 20 to 44 years [0.46, 0.37 to 0.57], and 45 to 64 years [0.55, 0.44 to 0.68]).

Motor vehicle crashes were the leading cause of injury death across the population, and the number of motor vehicle crash injury deaths increased sharply with increasing rurality (27.61/100,000 in most rural, 10.58/100,000 in most urban; RR 2.00; 95% CI 1.67-2.39)



(Table 2; Table E3, available online at <http://www.annemergmed.com>). Tests for linear trend across the rural urban continuum were significant ( $P<.001$  in unadjusted and fully adjusted models). Within each age subgroup, this finding remained constant, with a significantly increased risk of motor vehicle crash death in the most rural counties compared with the most urban in fully adjusted models.

For the entire population combined, as well as for most age subgroups, the top 3 causes of death were motor vehicle collisions, firearms, and poisoning (Figure 2). The only age groups with a different pattern were the youngest (0 to 14 years), in which the top 3 causes of death were motor vehicle crash, suffocation, and drowning; and the oldest ( $\geq 65$  years), in which the top 3 causes were falls, motor vehicle crashes, and firearms. Overall, firearms deaths showed no significant differences in risk of death between the most rural and most urban counties (Table 2). However, within the age subgroups, firearm deaths showed very different patterns across the rural urban landscape. In the youngest age group (0 to 14 years), as well as in the older age groups (45 to 64 years and  $\geq 65$  years), the risk of firearm related injury death was significantly higher in rural areas compared with the most urban (respectively, fully adjusted RRs: 1.64 [95% CI 1.10 to 2.46], 1.16 [95% CI 1.00 to 1.33], and 1.20 [95% CI 1.02 to 1.41]). However, in the 20 to 44 year old age group, the risk of firearm related injury death was significantly lower in the most rural areas compared with the most urban (0.85; 95% CI 0.73 to 0.99, fully adjusted). In the 15 to 19 year old age group, there was no significant difference. On the other hand, poisoning deaths showed a decreased risk of death in the most rural counties compared with the most urban counties in all except the 0 to 14 year old age group, in which there was no significant difference across rurality (fully adjusted RRs: all subjects 0.41 [95% CI 0.34 to 0.50], 15 to 19 years 0.55 [95% CI 0.39 to 0.78], 20 to 44 years 0.46 [95% CI 0.37 to 0.57], 45 to 64 years 0.40 [95% CI 0.33 to 0.49], and  $\geq 65$  years 0.69 [95% CI 0.53 to 0.90]). Finally, fall related injury deaths, a specific concern in the oldest age group ( $\geq 65$  years), had a significantly lower risk in the most rural areas compared with the most urban (0.69; 95% CI 0.52 to 0.92 fully adjusted).

In order to evaluate the possibility of effect modification on the association between injury related death rate and rurality, four covariates were studied; race, ethnicity, education level and income level. Rural counties with the highest quartile of percentage of black inhabitants showed no difference in the risk of injury death compared with urban counties with the highest quartile of black inhabitants (rural urban comparison 0.86; 95% CI 0.72 to 1.04). Rural counties with the highest quartile of black inhabitants showed a significantly lower risk of injury death compared with rural counties with the lowest quartile of black inhabitants (intrarural comparison 0.74; 95% CI 0.65 to 0.84). Urban counties with the highest quartile of black inhabitants showed no difference in the risk of injury death compared with urban counties with the lowest quartile of black inhabitants (intraurban comparison 1.02; 95% CI 0.83 to 1.25).

Rural counties with the highest quartile of percentage of Latino inhabitants had a significantly increased risk of injury death compared with urban counties with the highest quartile of Latino inhabitants (rural urban comparison 1.66; 95% CI 1.42 to 1.95). Rural counties with the highest quartile of Latino inhabitants had a significantly increased risk of

injury death compared with rural counties with the lowest quartile of Latino inhabitants (intrarural comparison 1.39; 95% CI 1.24 to 1.55). Urban counties with the highest quartile of Latino inhabitants showed no difference in risk of injury death compared with urban counties with the lowest quartile of Latino inhabitants (intraurban 0.64; 95% CI 0.33 to 1.25).

Rural counties with the highest quartile of percentage of college educated inhabitants showed a significantly increased risk of injury death compared with urban counties with the highest quartile of college educated inhabitants (rural urban comparison 1.49; 95% CI 1.26 to 1.76). Rural counties with the highest quartile of college educated inhabitants showed an increased risk of injury death compared with rural counties with the lowest quartile of college educated inhabitants (intrarural comparison 1.49; 95% CI 1.31 to 1.71). Urban counties with the highest quartile of college educated inhabitants showed no difference in the risk of injury death compared with urban counties with the lowest quartile of college educated inhabitants (intraurban comparison 0.93; 95% CI 0.83 to 1.04).

Rural counties with the highest quartile of median income showed an increased risk of injury death compared with urban counties with the highest quartile of median income (rural urban comparison 1.89; 95% CI 1.54 to 2.32). Rural counties with the highest quartile of median income showed an increased risk of injury death compared with rural counties with the lowest quartile of median income (intrarural comparison 1.22; 95% CI 1.03 to 1.46). Urban counties with the highest quartile of median income showed no difference in risk of injury death compared with urban counties with the lowest quartile of median income (intraurban mrucc 0: 1.12; 95% CI 0.68 to 1.84) but did show a lower risk of injury death among the next most urban counties (intraurban comparison mrucc 1: 0.62, 95% CI 0.50 to 0.76 and mrucc 2: 0.83, 95% CI 0.71 to 0.96).

Testing for spatial autocorrelation among the residuals using the Moran's I statistic showed a significant level of autocorrelation ( $P<.01$ ). Testing for spatial autocorrelation among the residuals using the Geary's c test did not show significant autocorrelation ( $P=.11$ ).

We determined the number of trauma centers in each county and its surrounding counties as a measure of proximity to trauma center care. For each county, the total number of trauma centers in that county and surrounding counties ranged from 0 to 38, with 61.7% of counties having no trauma centers (Level I and II) in their own or a surrounding county. Adding this variable to the model had minimal attenuating effect on the association between injury related mortality rate and urban rural nature of the county (Table 2).

## LIMITATIONS

Although we broadly evaluated all injury deaths across the United States, nonfatal injuries could not be included, and we recognize that this limits the robustness of our analysis, and the evaluation of "safety" based only on fatal injuries is incomplete. We were able to control for a wide variety of county level variables that may have confounded the relationship between the risk of injury death and the rural/urban category of the county, but residual confounding may remain. Important variables that we are unable to adjust for are distance to a trauma center, injury severity, rates of alcohol and substance abuse, and estimates of motor



vehicle use. The addition of distance to a trauma center would help to hone in on the reason behind results found here, and this is an important next step to this work. Ecologic bias may also exist, but the design and intent of the study are for public health decision making in the aggregate and not at the level of individuals. We recognize that the experience of any individual within a county does not necessarily represent the injury related mortality risk level of the overall county. In addition, we recognize that not all counties within a rural urban category experience the same risk level. This is demonstrated in small part by the wide range of injury death rates displayed across the most urban counties shown in Figure 1. Finally, we used death certificate data in our analysis, and although manner of death is known to be complete in such data,<sup>42</sup> misclassification of intent or mechanism may exist.<sup>43</sup> We have no reason to believe that this misclassification would systematically vary across the rural urban spectrum, and therefore any bias introduced should be random and bias toward the null, decreasing our ability to detect a true difference.

We chose to exclude terrorist related deaths, the majority of which are associated with the September 11, 2001 attacks on the United States. Given the infrequent, unpredictable, and devastating nature of these attacks, it seemed unreasonable to include these deaths in an evaluation of overall trends of injury related deaths across the nation. It is difficult to determine the direction of bias, given that deaths occurred both in rural and urban areas, but it is our belief that the “true” evaluation of injury related deaths in the United States does not include these outliers. In addition, the data years included in this analysis are somewhat dated because of the limitation on data available for our special data agreement, under which we are able to include data for the smallest counties (which are typically excluded because of their higher degree of identifiability). Although these relationships may have changed in the years since our data set ended, as new trauma centers have been verified and changes in injury prevention have occurred, we observed little change in the rate of injury deaths during the period under study (incidence difference between 1999 and 2006 nonsignificant at 8 per 100,000; 95% CI 15 to 31 per 100,000).

Finally, given the constraints of our model, we were able to adjust directly for longitudinal correlation, which we believe is the strongest correlation component, but were not able to adjust directly for spatial autocorrelation. To evaluate its effect, we tested the residuals of our model for spatial autocorrelation. One of the 2 classic tests of spatial autocorrelation that we used found significant spatial autocorrelation among the residuals and one did not. Disparate results from spatial testing have been observed in simulation models because of differences in map shape and regional structures, as well as with heteroscedasticity caused by unequal variances.<sup>44,45</sup> Given the disparate results from the 2 classic tests for spatial autocorrelation, we decided to evaluate the effect of direct adjustment for the average injury mortality rates of surrounding counties. With the addition of average surrounding injury mortality for each county as a covariate in the fully adjusted model of all injury mortality risk, we found little effect on the association between rurality and injury mortality (RR 1.13; 95% CI 1.00 to 1.29, most rural compared with most urban). The lack of significant change in the main effect of the model makes the likelihood of residual spatial autocorrelation less. However, we recognize that some unmeasured spatial autocorrelation may remain in our models, but given the obvious tendency for rural areas to be near one another, and likewise

urban areas, it may be that residual spatial autocorrelation should be expected for outcomes that are affected by the rural/urban nature of county locations.

## DISCUSSION

Despite public perception to the contrary,<sup>12,46,47</sup> when all types of injuries are considered together, rural areas, not urban, bear a disproportionate amount of injury related mortality risk in the United States. Although variability among urban areas clearly exists (see Figure 1 city comparisons), when urban areas were considered as a group, risk of serious injury resulting in death was approximately 20% lower than in the most rural areas of the country. Although our findings support the belief that homicide rates and risk of homicide are significantly higher in urban areas compared with rural,<sup>48</sup> we demonstrate that the magnitude of homicide related deaths, even in urban areas, is outweighed by the magnitude of unintentional injury deaths, particularly those resulting from motor vehicles. In fact, the rate of unintentional injury death is more than 15 times that of homicide among the entire population, with the risk resting heavily in rural areas such that the risk of unintentional injury death is 40% higher in the most rural counties compared with the most urban.

Motor vehicle crash deaths drive this finding as the top mechanism of injury death, occurring at a rate that is more than 1.4 times higher than the next leading mechanism of injury death overall and twice the next leading mechanism in rural areas (Figure 2).<sup>49,50</sup> By comparison, the risk of motor vehicle crash death in the most rural areas is 2 times that in the most urban areas. Factors likely to contribute to this elevated rural risk include speed of travel,<sup>51</sup> increased risk taking,<sup>52</sup> adherence to traffic laws,<sup>53</sup> and distance to medical care.<sup>54</sup> Education, prevention efforts, and evaluation of the trauma system to minimize distance to medical care are therefore possible interventions that may reverse this injury related mortality risk difference. Although by and large the increased injury related mortality risk to rural residents is driven by these motor vehicle crash related injury deaths, other less common injury mechanisms with increased risk of death in rural areas include machinery injuries, injuries from being struck, and environmental/exposure injuries (Table E3, available online at <http://www.annemergmed.com>).

Differences across age groups in both primary injury mechanism and magnitude across the rural urban spectrum are important to consider as local injury prevention priorities are being considered. For example, from the data presented here, we can see that understanding the increased risk of fall related deaths in the urban elderly and drowning in urban children are important to allow tailored prevention and treatment efforts to maximally benefit local safety (Figure 2). In addition, understanding of the magnitude of injury mechanism by location can lead to efforts to equip local hospitals to care for the injuries that they are most likely to encounter.

These findings can also be considered in the context of the ongoing ED workforce debate. Hospitals in rural areas are less frequently staffed by emergency physicians and have less access to on call specialists, including trauma surgeons, neurosurgeons, and orthopedists.<sup>23,55</sup> Although the emergency medicine trained and board certified workforce has the most direct training in the care of the severely injured patients among the physician

types who may staff EDs, it is unlikely that the workforce pool of emergency medicine trained physicians will be large enough to cover all EDs completely at any point in the near future.<sup>23,56,57</sup> The fact that the injury related mortality risk is highest in the areas least likely to be covered by emergency physicians and least likely to have access to trauma care (<http://www.traumamaps.org>) could be used to support ongoing efforts to improve emergency and trauma care systems in the United States, using a population planning approach.<sup>18,58,59</sup> Additional efforts should focus on expanding access to expert care by using less traditional methods, including certification or postresidency training programs for physicians who will be providing care in EDs from non emergency medicine backgrounds and the continued examination of how technology based solutions, including telemedicine, can expand the traditional reach of medical expertise into rural areas.<sup>60–62</sup>

Through our evaluation of interactions between the rural urban nature of the counties and adjusting variables, we have found some interesting differences in the risk of injury death by subpopulations within counties. For example, among counties with the highest percentage of black inhabitants, we do not observe the same rural urban trend of increasing injury death risk in rural areas that we do in the entire population. In addition, rural areas with the highest percentage of black inhabitants were found to be relatively safer than rural areas with lower percentages of black inhabitants, whereas no similar difference was observed in urban areas. Given the focus and intent of this study, these results are hypothesis generating only but lead to interesting avenues of research. Given the lower rate of suicide among the black community,<sup>63</sup> coupled with the high overall rate of suicide in rural areas, it may be that a higher percentage of black inhabitants is protective, at least in part, for this reason. Or one could postulate that rural counties with the highest quartile of black population tend to be farther from highways; with motor vehicle injury the main driver of the increased injury death risk in rural areas, this would help to reverse the rural urban trend, as we see here.

Evaluation of income and education found that counties within the highest quartile of income and education showed the same increased risk of injury death with increasing rurality found in the overall county group. However, among the most rural counties, those with higher education and income levels had a higher risk of injury death than those with the lowest education and income levels. This difference was not generally observed among the most urban counties. Once again, these findings are hypothesis generating and could lead to interesting focused evaluation of the reasons behind these differences. We could postulate that the counties with higher income and education levels in rural areas are more likely to be found near universities, larger hospitals, or larger employers, and that may influence the differences we have found among this subpopulation, but further studies are needed to test these inferences.

Our analysis was completed according to the county of injury death occurrence to assess the safety risk of time spent in each county and the safety risks inherent in the county itself. However, it is likely that results would be similar if the county of residence were used because previous work has shown that the majority of injuries occur close to home.<sup>26</sup> In some ways, counties with a large highway, airport, or train station, or those with a large tourist population, may have a larger effective population than their true residential population, given the number of people who are visiting the area at any given time

compared with those who are registered inhabitants. It is unclear whether this would tend to affect rural areas or urban areas more because more of these areas are likely to occur in urban counties, but the effect on the population may be greater in sparsely inhabited areas. Future analyses may be able to adjust for these differences to validate the results found here, but the likelihood of injury occurring close to home makes it likely that our results would still be found valid. In any event, with the analysis structured in this way, it informs the individual in a logical manner by speaking to the relative risk of fatal injury according to the exposure to a given county type.

One postulated mechanism through which differences in injury related death may vary by rurality of the county could be proximity to a trauma center. It is known that rural counties have fewer trauma centers and that inhabitants of rural counties are more likely to lack reasonable access to higher level trauma care.<sup>18,64,65</sup> It is also known that higher level trauma center care improves outcomes for injured patients.<sup>66</sup> It is thus reasonable to consider access to specialized care, or lack thereof, as a mediator of the relationship between the rural nature of a county and its level of injury related mortality. To address this issue, we introduced a variable related to access to trauma center care into our model as a covariate to determine whether it would erase the increased injury related mortality risk that we observed to be associated with the most rural counties. In fact, we observed very little change in the rural urban relationship when we accounted for “access” to trauma center care. This would argue against access to specialized care being the driving force behind the disparity in injury related mortality found for rural areas. We were able to use only a simple count of trauma centers per county as our determination of access to care, and it is possible that a more sophisticated model of trauma center access, using true distances and drive times, could have more influence on this relationship. However, given the very minor effect of our crude adjustment variable, it is unlikely that the addition of a more accurate access variable would account for all of the increased risk of injury related mortality found in the most rural counties compared with the most urban.

Although past work has shown that county population density is inversely correlated with the risk of overall injury death<sup>67</sup> and that unintentional trauma deaths across counties have hot spots in rural areas,<sup>68</sup> this is the first study to focus on the total rates of injury mortality for all US counties across a detailed rural urban continuum and the first to provide an understanding of the relation between age and injury type and intent, to our knowledge. Our findings suggest that urban living is relatively safe when safety is measured in terms of injury death, and we support the belief that urban rural differences are important for consideration in injury prevention efforts. We recognize that although our analysis is complete in that it includes all injury deaths across the country, it does not include injuries that do not result in death. Therefore, left open is the question about how the access and quality of care available across the country affect the differences that we have found in injury mortality. We postulate that the trends that we have found are primarily due to injury occurrence as opposed to differences in care because both Coben et al<sup>69</sup> and Sihler and Hemmila<sup>70</sup> have found similar differences in nonfatal injury hospitalization and disability across the rural urban landscape. However, this question remains open to further study. Next steps should focus on creating local injury prevention priority scores<sup>71</sup> and considering the prioritization of trauma center placement in the most at risk areas, in addition to verification

of the contribution of injury care by the evaluation of nonfatal injuries across the rural urban landscape.

When considering all mechanisms of injury death as an overall metric of safety, large cities appear to be the safest counties in the United States, significantly safer than their rural counterparts. Greater emphasis on elevated safety risks outside of large US cities is in order, alongside a changed perception of urban living as a relatively safe experience. Future efforts should focus on identifying local injury prevention priorities, considering the effect of these findings on the certification and training requirements for ED staffing, and applying these findings to the ongoing development of trauma and emergency care systems in the United States, using a population health perspective.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Editor's Capsule Summary****What is already known on this topic**

Injury is the leading cause of death in individuals aged 1 to 44 years in the United States, with higher reported rates of crime and homicide in urban areas.

**What question this study addressed**

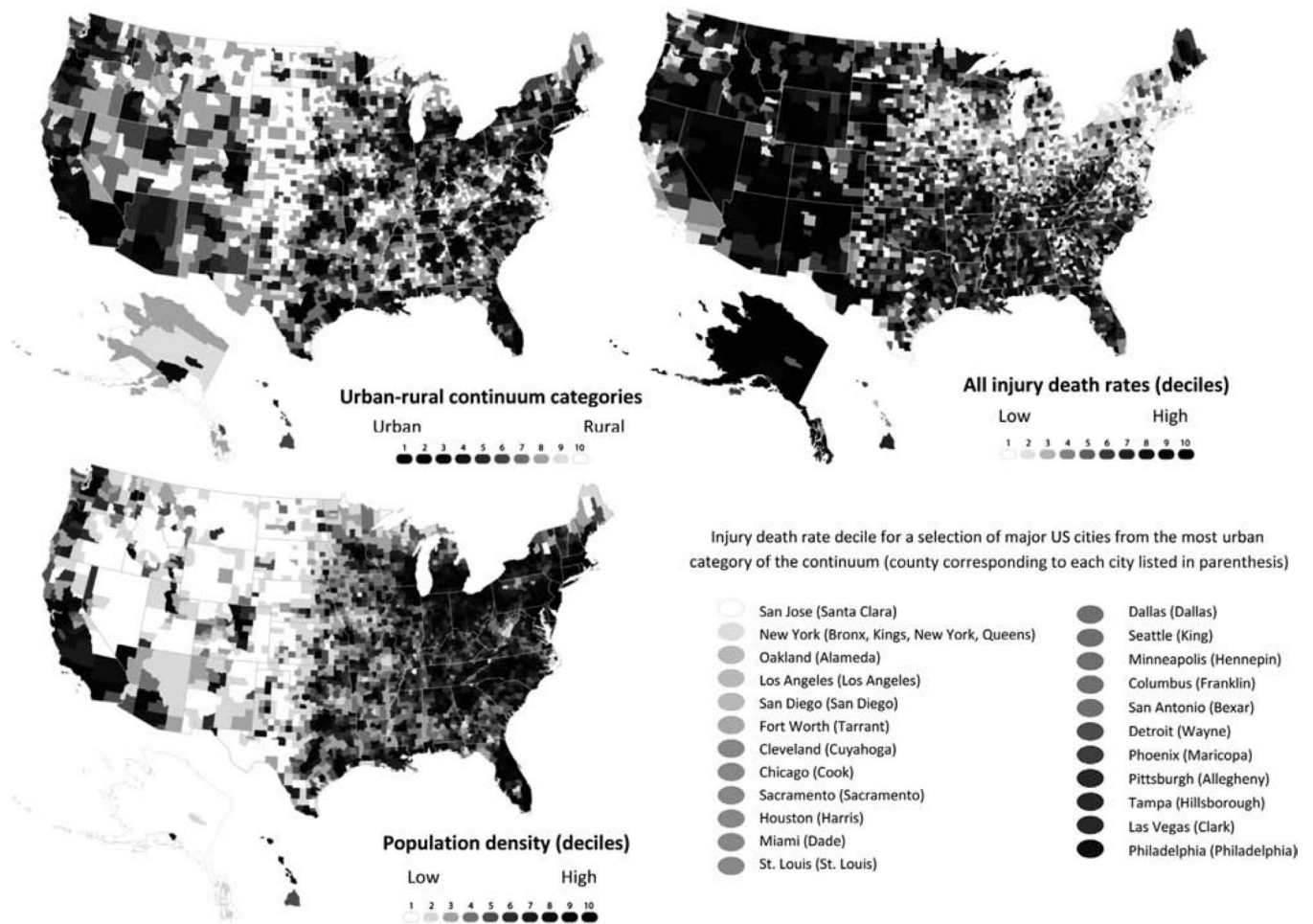
Are there fewer injury-related deaths in non-urban areas?

**What this study adds to our knowledge**

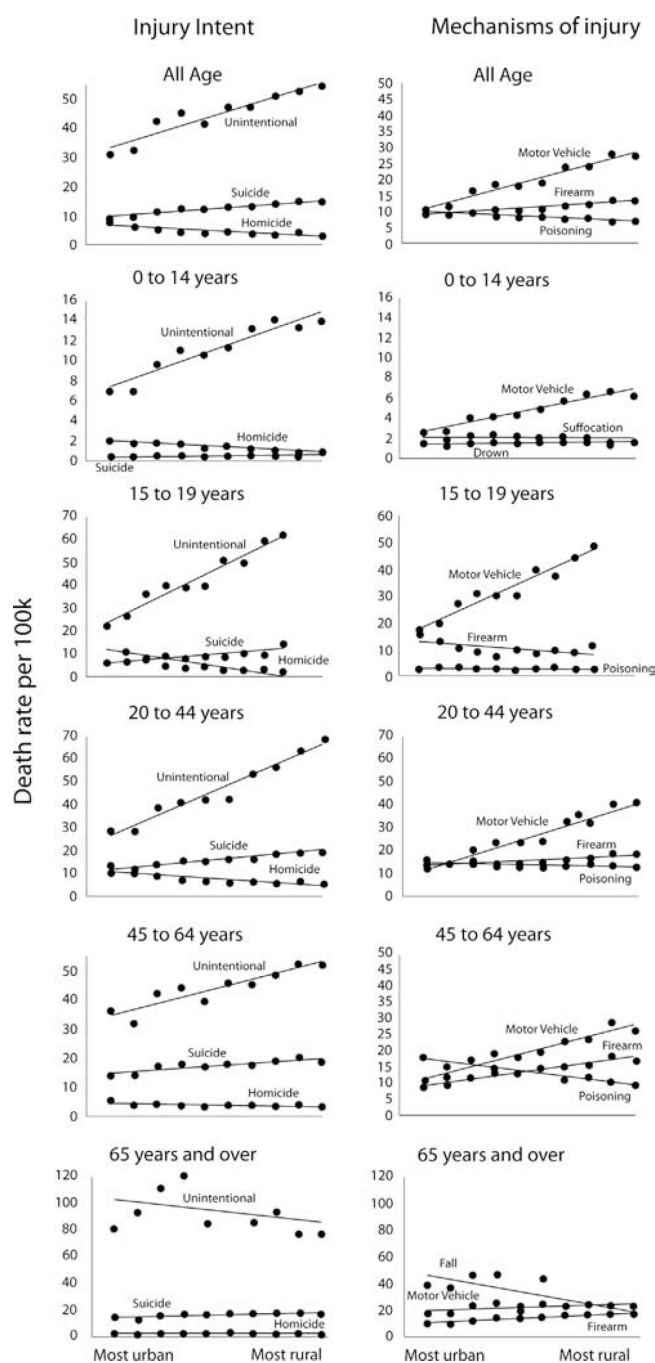
In this time-series analysis of 1,295,929 injury-related deaths in the United States, overall injury and vehicular trauma death rates were higher in rural areas. This pattern was not seen in firearm-related death rates.

**How this is relevant to clinical practice**

Although not directly relevant to clinical care, these data support improving access to trauma centers in rural areas, as well as continued violence prevention efforts in all locales.



**Figure 1.**  
Decile maps of all US counties of major cities comparing urban-rural continuum, population density and injury death rates.



**Figure 2.** Death rates per 100,000 population across the rural-urban continuum by intent and for the top three mechanisms of injury, overall and within subgroups by age.

**Table 1**

Mortality for all types of injuries combined, comparing the most urban and the most rural counties and separated by age groups.

Age Groups, Years	Most Urban (Deaths/100,000 People)	Most Rural (Deaths/100,000 People)	Unadjusted Rate Ratios (Baseline=Most Urban, 95% CI)	Adjusted RR Injury Death* (Baseline=Most Urban, 95% CI)
0-14	9.49	16.10	1.64 (1.34-2.00) TFT 1.07 (1.06-1.09)	1.23 (1.01-1.50) TFT 1.02 (1.01-1.03)
15-19	45.65	79.53	1.80 (1.54-2.10) TFT 1.06 (1.05-1.07)	1.29 (1.10-1.52) TFT 1.02 (1.01-1.03)
20-44	54.76	96.28	1.82 (1.55-2.14) TFT 1.07 (1.06-1.08)	1.24 (1.07-1.43) TFT 1.02 (1.01-1.02)
45-64	57.66	75.34	1.33 (1.15-1.54) TFT 1.04 (1.04-1.05)	1.12 (0.99-1.27) TFT 1.01 (1.00-1.01)
65	53.66	67.95	0.93 (0.79-1.10) TFT 0.99 (0.98-1.00)	1.15 (0.99-1.34) TFT 1.00 (0.99-1.01)
All ages	49.72	73.76	1.54 (1.33-1.78) TFT 1.05 (1.04-1.06)	1.22 (1.07-1.39) TFT 1.01 (1.01-1.02)

TFT, Test for trend across the modified rural-urban continuum.

\* Adjusted for year, median income, region of the country, and percentage of adults living alone, male subjects, blacks, Latinos, college educated, and unemployed.



Table 2

Adjusted rate ratios for all injury death, by intent and for the most common mechanisms of injury death.

	All Injuries				Suicide			
	Unadjusted		Reduced*		Unadjusted		Reduced <sup>§</sup>	
	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>
Most urban (0)	Ref		Ref		Ref		Ref	
Code 1	0.97 (0.8 1.1)	1.11 (1.0 1.3)	1.12 (1.0 1.3)	1.10 (1.0 1.2)	1.12 (1.0 1.3)	1.25 (1.1 1.4)	1.13 (1.0 1.3)	
Code 2	1.15 (1.0 1.3)	1.12 (1.0 1.3)	1.12 (1.0 1.3)	1.10 (1.0 1.3)	1.25 (1.1 1.4)	1.22 (1.1 1.4)	1.1 (1.0 1.2)	
Code 3	1.21 (1.1 1.4)	1.11 (1.0 1.3)	1.1 (1.0 1.2)	1.07 (0.9 1.2)	1.32 (1.2 1.5)	1.22 (1.1 1.4)	1.08 (1.0 1.2)	
Code 4	1.15 (1.0 1.3)	1.05 (0.9 1.2)	1.06 (0.9 1.2)	1.03 (0.9 1.2)	1.31 (1.2 1.5)	1.19 (1.1 1.3)	1.07 (1.0 1.2)	
Code 5	1.28 (1.1 1.5)	1.1 (1.0 1.3)	1.08 (1.0 1.2)	1.06 (0.9 1.2)	1.36 (1.2 1.6)	1.18 (1.0 1.3)	1.06 (0.9 1.2)	
Code 6	1.30 (1.1 1.5)	1.11 (1.0 1.3)	1.12 (1.0 1.3)	1.10 (1.0 1.3)	1.36 (1.2 1.5)	1.21 (1.1 1.3)	1.07 (1.0 1.2)	
Code 7	1.41 (1.2 1.6)	1.13 (1.0 1.3)	1.14 (1.0 1.3)	1.11 (1.0 1.3)	1.49 (1.3 1.7)	1.20 (1.1 1.3)	1.07 (1.0 1.2)	
Code 8	1.51 (1.3 1.8)	1.22 (1.1 1.4)	1.23 (1.1 1.4)	1.21 (1.0 1.4)	1.56 (1.4 1.8)	1.27 (1.1 1.4)	1.12 (1.0 1.3)	
Most rural (9)	1.54 (1.3 1.8)	1.20 (1.1 1.4)	1.22 (1.1 1.4)	1.19 (1.0 1.4)	1.55 (1.4 1.8)	1.20 (1.1 1.4)	1.06 (1.0 1.2)	

	Motor Vehicle Crashes				Firearm			
	Unadjusted		Reduced <sup>†</sup>		Unadjusted		Reduced <sup>†</sup>	
	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>	Ref	Full <sup>†</sup>
0.59 (0.5 0.8)	0.70 (0.6 0.8)	1.31 (1.1 1.6)	1.46 (1.2 1.7)	1.42 (1.2 1.7)	0.95 (0.8 1.1)	0.98 (0.9 1.1)	0.98 (0.9 1.1)	
0.60 (0.5 0.8)	0.67 (0.6 0.8)	1.69 (1.4 2.0)	1.55 (1.3 1.8)	1.52 (1.3 1.8)	1.05 (0.9 1.2)	0.91 (0.8 1.0)	0.91 (0.8 1.0)	
0.53 (0.4 0.7)	0.54 (0.5 0.6)	1.82 (1.5 2.2)	1.55 (1.3 1.8)	1.51 (1.3 1.8)	1.07 (0.9 1.3)	0.84 (0.8 0.9)	0.84 (0.8 0.9)	
0.49 (0.4 0.6)	0.50 (0.4 0.6)	1.67 (1.4 2.0)	1.44 (1.2 1.7)	1.40 (1.2 1.7)	1.06 (0.9 1.2)	0.82 (0.7 0.9)	0.82 (0.7 0.9)	
0.55 (0.4 0.7)	0.49 (0.4 0.6)	1.75 (1.4 2.2)	1.42 (1.2 1.7)	1.40 (1.2 1.7)	1.12 (0.9 1.3)	0.85 (0.7 1.0)	0.85 (0.7 1.0)	
0.51 (0.4 0.7)	0.46 (0.4 0.5)	2.24 (1.9 2.7)	1.74 (1.5 2.1)	1.69 (1.4 2.0)	1.21 (1.0 1.4)	0.85 (0.8 1.0)	0.85 (0.8 1.0)	
0.47 (0.4 0.6)	0.43 (0.4 0.5)	2.30 (1.9 2.8)	1.72 (1.4 2.0)	1.69 (1.4 2.0)	1.25 (1.1 1.5)	0.86 (0.8 1.0)	0.85 (0.8 1.0)	
0.55 (0.4 0.7)	0.51 (0.4 0.6)	2.81 (2.3 3.4)	2.15 (1.8 2.6)	2.08 (1.7 2.5)	1.44 (1.2 1.7)	0.96 (0.8 1.1)	0.96 (0.8 1.1)	
0.43 (0.3 0.6)	0.44 (0.4 0.5)	2.75 (2.3 3.3)	2.05 (1.7 2.4)	2.00 (1.7 2.4)	1.38 (1.2 1.6)	0.91 (0.8 1.0)	0.91 (0.8 1.0)	

\* Variables included in reduced model: year, median income, percentage of adults living alone, region.

<sup>†</sup> Variables included in full model: year; median income; region of the country; and percentage of adults living alone, male subjects, blacks, Latinos, college educated, and unemployed.

<sup>‡</sup> Full model with the addition of covariate representing the total number of Level I and II trauma lefts in that county and surrounding counties.

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§ Variables included in reduced model: year; median income; region; and percentage of adults living alone, male subjects, and blacks.

¶ Variables included in reduced model: year; median income; region; and percentage of adults living alone, male subjects, blacks, Latinos, college educated, and unemployed (all covariates found to be important in model building sequence).

¶ Variables included in reduced model: year; median income; region; and percentage of blacks, Latinos, and unemployed.

# Variables included in reduced model: median income; region; and percentage of adults living alone, blacks, Latinos, and college educated.