Identifying Targets for Potential Interventions to Reduce Rural Trauma Deaths: A Population-Based Analysis

David Gomez, MD, Myriam Berube, Wei Xiong, MSc, Najma Ahmed, MD, PhD, Barbara Haas, MD, Nadine Schuurman, PhD, and Avery B. Nathens, MD, PhD

Background: Rural environments have consistently been characterized by high injury mortality rates. Although injury prevention efforts might be directed to reduce the frequency or severity of injury in rural environments, it is plausible that interventions directed to improve injury care in the rural settings might also play a significant role in reducing mortality. To test this hypothesis, we set out to examine the relationship between rurality and the setting in which patient death was most likely to occur.

Methods: This is a population-based retrospective cohort study evaluating all trauma deaths occurring in the province of Ontario, Canada, over the interval 2002 to 2003. Patient cohorts were defined by their potential to access trauma center care using two different approaches, rurality and timely access to trauma center care.

Results: There were 3,486 deaths over the study interval, yielding an overall injury mortality rate of 14.6 per 100,000 person-years. Overall, more than half of deaths occurred before reaching an emergency department (ED). Prehospital deaths were twice as likely in the most rural locations and in those with limited access to timely trauma center care. However, among patients surviving long enough to reach hospital, there was a threefold increase in the risk of ED death among those injured in a region with limited access to trauma center care.

Conclusions: We demonstrate that a significant proportion of deaths occur in rural EDs. This study provides new insights into rural trauma deaths and suggests the potential value of targeted interventions at the policy and provider level to improve the delivery of preliminary trauma care in rural environments.

Key Words: Rural health, Trauma centers, Geographic information systems.

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Rural environments account for over 85% of the North American land mass. Although less than one fifth of the population live in a rural area, the populations in these regions account for a disproportionate number of trauma-related deaths. Rural environments have consistently been characterized by high injury mortality rates. The factors leading to these higher injury mortality rates are believed to be many including a lower rate of use of protective devices; motor vehicle crashes might be of greater severity due to higher speeds; and discovery time tends to be prolonged. In addition, prehospital and rural health care providers attend to severely injured patients very infrequently and might be challenged by limited local resources. These factors, in concert with the potentially prolonged time to definitive care, might play a role in the observed higher mortality rates in the rural setting.

Although primary and secondary injury prevention efforts might be directed to reduce the frequency or severity of injury in rural environments, it is evident that interventions directed to improve injury care among those who sustain severe injuries might also play a significant role in reducing mortality. To better direct such interventions, we employed a novel population-based approach to examine the relationship between rurality and the setting in which patient death was most likely to occur. We demonstrate that, compared with more urban patients, a significant proportion of deaths among patients from rural areas occurs in emergency departments, suggesting that opportunities exist for directed interventions to enhance the educational or physical resources available to providers working in these environments.

METHODS

Study Design

This is a retrospective population-based cohort study evaluating all trauma deaths occurring in the province of Ontario, Canada, in the interval between 2002 and 2003. The principle aim of this study was to examine the relationship between potential access to definitive trauma care and the subsequent location of death along the care continuum. This project was reviewed and approved by the St. Michael’s Hospital Ethics Research Board.

Setting

The province of Ontario is Canada’s most populous province with almost 13 million inhabitants and encompasses a land area of 415,598 square miles (almost twice the size of Texas). Over 90% of the geographic area is considered rural. Approximately 15% of the population is at least 100 km (60 miles) from any physician specialist, let alone a designated trauma center. Ontario has 9 designated Level I adult trauma centers, all of which are located in urban areas. There are no lower level designated centers, and nondesignated...
centers are not required to have a trauma team nor is advanced trauma life support (ATLS) a requirement to work in an emergency department. Distances are vast such that the mean provincial prehospital time (i.e., from injury to definitive trauma center care) is 62 minutes for those transported directly to a trauma center from the scene. If transported to a nondesignated center first, the average time between injury and trauma center care is over 6 hours.

Data Sources and Inclusion Criteria

Traumatic deaths were identified in the period between 2002 and 2003 (the most recent available data) from a subset of the Ontario Trauma Registry collated by the Chief Coroner: the Ontario Trauma Registry Death Data Set (DDS). This is a population-based registry of all deaths with an external cause of injury occurring within the geographic borders of Ontario. We excluded deaths due to asphyxiation, burns, drowning, electrocution, intoxication, and same level falls, because the natural history of these injuries differs significantly from those caused by other external mechanisms. In addition to patient characteristics and mechanism of injury, the DDS provides both geographic location of death (census subdivision [CSD]) and the environment in which death occurred (field, emergency department, operating room, and other in-hospital). Although all patients in the dataset were ultimately patients who died, for the purposes of this analysis, we considered patients dying in the emergency department or beyond (i.e., in hospital) as “potentially salvageable,” because these patients had potential access to life-saving interventions.

Measures of Access to Care: Cohort Definitions

Patient cohorts were defined by their potential for access to trauma center care. Access was evaluated using two different approaches. In the first approach, we defined access as a function of rurality. We classified each CSD in Ontario using data from the 2001 Canadian census into one of three strata of rurality: <1%, 1–50%, and >50% rural. These strata were defined by the proportion of the population in that CSD living in a rural environment. Rural environments were defined as small towns, villages, and other populated places (estate lots, agricultural lands, and remote and wilderness areas) with a population of less than 1,000 people. In the second approach, we defined access as a measure of land transport time from the location of injury to the nearest designated trauma center. Access time was categorized as either ≤1 hour or >1 hour. A vector-based geographic information system (GIS) network analysis was used to model a 1 hour land transport catchment areas for all trauma centers in the province. This approach more adequately defines road transport times than the “crow flies” (straight line) approach, because it takes into account geographic barriers (bodies of water and mountain ranges), travel impedance (speed limits), and travel impactors (traffic light and stop signs). A transport time of 1 hour was selected as this represents the 90th percentile of transport times submitted by emergency medical services (EMS) agencies contributing data to the National EMS Information Systems in those environments classified at the outer limits of rurality (referred to as “wilderness”). We acknowledge that this represents the outer limit of transport times. We selected land transport times as the majority of patients are transported from the incident site to the first hospital providing care by land ambulance. Currently, there is no means of linking EMS data to the DDS, thus it is not possible to evaluate at the record level precisely how individual patients were transported.

Statistical Analysis

Less than 5% of deaths were classified at the level of the census division (CD), rather than the CSD. These deaths were assigned to the CSD level using a simple imputation strategy based on the known distribution of their respective CD. Means and standard deviations are presented for continuous variables, and absolute and relative frequencies are presented for discrete variables. Means were compared using the t test or Kruskal-Wallis test for nonparametric data. Proportions were evaluated using the χ² test. Adjusted relative risks and their 95% confidence intervals (CIs) were estimated using Poisson regression. All data were analyzed using SAS (version 9.1, Cary, NC).

RESULTS

There were 3,486 deaths over the study time interval, yielding an overall injury mortality rate of 14.6 per 100,000 person-years. Almost two thirds of deaths occurred in the 15 to 54 years age group, and three quarters of patients were men (Table 1). Motor vehicle collisions were responsible for over half of all deaths. The majority of deaths (54%, n = 1,877) occurred in the field, before any hospital contact (Table 2). Modeling trauma center catchment areas revealed that only 15% of the population lived beyond 1 hour of a trauma center (Fig. 1). However, this small proportion of the population accounted for 37% of all trauma-related deaths over this time interval.

We examined differences in patient and injury characteristics across our measures of access to trauma center care. Although there were no significant differences in gender distribution, more limited access (defined by either approach) was associated with a disproportionately higher number of deaths in younger age groups. Additionally, there were significant differences in the proportion of the mechanism of injury, with a higher proportion of motor-vehicle crash-related deaths and fewer fall-related deaths in environments with limited access (Table 1).

Figure 2 demonstrates the relationship between age- and gender-adjusted injury mortality rates and trauma center catchment areas. The CDs with the highest adjusted injury mortality rates lay clearly outside the trauma center 1 hour land travel catchment areas. Conversely, most of the CDs with the lowest injury mortality rates had timely access to trauma center care.

To provide insights into potential mechanisms underlying the higher mortality rates in environments with limited access to definitive trauma care, we evaluated where in the trauma care continuum patients were dying. The distribution of deaths in the most rural environments was very similar to the distribution of deaths outside the 1 hour catchment area. Both were remarkable for a very high (>75%) proportion of field deaths (Table 2). Further, there was clearly a gradient
with increasing rurality. The crude relative risk of scene deaths was 2.0 (95% CI 1.8–2.1) times greater in the most rural environments compared with the least. Similar findings were evident using our alternate definition of limited access based on transport time (1 hour) (relative risk [RR] 1.9 [95% CI 1.8–2.0]).

We next considered the site of death among those surviving long enough to reach hospital. Among this cohort, there was a greater proportion of ED deaths in environments with limited access to trauma center care (Table 3). The relative risk of dying in the ED (vs. the operating room or other in-hospital environment) was 50% greater in the most rural CSDs compared with the least rural (RR 1.5 [95% CI 1.2–1.8]). The findings were similar using our definition of limited access based on catchment area: the relative risk of death in the ED among those surviving to reach hospital was 1.7 (95% CI 1.5–1.9) times greater in CSDs outside the 1 h catchment area compared with those within the catchment area of a trauma center.

The risk of ED death among those surviving to hospital in environments with limited access might be confounded by age, gender, or mechanism of injury. To further explore the relationship between deaths and access, we developed a logistic regression model to adjust for differences in these potential confounders. The adjusted odds of ED death among those surviving to hospital was 3.5 (95% CI 2.5–4.9) times greater in CSDs remote (>1 hour) from definitive trauma center care compared with patients who died in regions with immediate access to definitive care. Although the adjusted odds of death in comparing the most rural to the least rural environments was not significantly different from one (OR 0.6 [95% CI 0.4–1.1]), those living in moderately rural regions (1–50% of population living in a rural environment) had clear evidence of a higher risk of ED death compared with the least rural environments (OR 1.3 [95% CI 1.01–1.62]).

**DISCUSSION**

Rural environments are characterized by higher injury mortality rates when compared with their urban counterparts. The factors leading to these higher rates are many and include a greater propensity for high-risk behaviors such as speeding and inappropriate use of protective devices; higher prevalence of alcohol use while driving; higher prevalence of loaded unlocked firearms at home; environmental factors such as exposure to agricultural machinery; and prolonged discovery times. Further, limited or delayed access to trauma care may play a central role in the observed higher mortality rates in the rural setting. We set out to evaluate the extent to which limited access to resources might play a role in this higher mortality.

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**TABLE 1.** Baseline Injury Characteristics and Cause of Death by Potential Access to Trauma Care

<table>
<thead>
<tr>
<th></th>
<th>All Deaths n (%)</th>
<th>Rurality</th>
<th>Transport Times</th>
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<tr>
<td></td>
<td>&lt;1%</td>
<td>1–50%</td>
<td>&gt;50%</td>
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<tr>
<td>Census subdivisions (n)</td>
<td>129</td>
<td>33</td>
<td>73</td>
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<tr>
<td>Deaths (n)</td>
<td>3486</td>
<td>1348 (39)</td>
<td>1691 (49)</td>
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<tr>
<td>Male gender</td>
<td>2529 (73)</td>
<td>976 (72)</td>
<td>1232 (73)</td>
</tr>
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<td>Age (yr)</td>
<td>0.004</td>
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<td></td>
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<tr>
<td>0–14</td>
<td>117 (3)</td>
<td>38 (3)</td>
<td>62 (4)</td>
</tr>
<tr>
<td>15–54</td>
<td>2150 (62)</td>
<td>786 (38)</td>
<td>1078 (64)</td>
</tr>
<tr>
<td>&gt;55</td>
<td>1219 (35)</td>
<td>524 (39)</td>
<td>551 (32)</td>
</tr>
</tbody>
</table>
| Mechanism               | MVC, motor vehicle collision.

**TABLE 2.** Site of Death by Potential Access to Trauma Care

<table>
<thead>
<tr>
<th></th>
<th>All Deaths n (%)</th>
<th>Rurality</th>
<th>Transport Times</th>
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<tbody>
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<td>Deaths (n)</td>
<td>3486</td>
<td>1348 (39)</td>
<td>1691 (49)</td>
</tr>
<tr>
<td>Location</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field</td>
<td>1877 (54)</td>
<td>530 (39)</td>
<td>1000 (59)</td>
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<tr>
<td>ED</td>
<td>727 (21)</td>
<td>322 (24)</td>
<td>348 (21)</td>
</tr>
<tr>
<td>OR</td>
<td>124 (4)</td>
<td>85 (6)</td>
<td>36 (2)</td>
</tr>
<tr>
<td>Other in-hospital</td>
<td>755 (22)</td>
<td>411 (31)</td>
<td>307 (18)</td>
</tr>
</tbody>
</table>

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Using a unique population-based database, we explored the relationship of access to care with the site of death along the trauma care continuum. We postulated that by understanding this relationship, we would identify opportunities for targeted interventions in environments with limited access to definitive care. Typically, rural is often used as a surrogate for limited access. As access and rurality might not be tightly coupled, we sought an additional means of identifying potentially limited access to care. We employed a vector-based GIS network analysis to model 1 hour land travel catchment areas for all of the trauma centers in the region.

Taking the approach described, we identified a high proportion of scene deaths among patients injured in areas with limited access, an expected finding. However, what is unique is the identification of a significantly higher proportion of deaths in the ED among those surviving long enough to reach hospital. Specifically, there is a threefold greater odds of ED death compared with deaths further along the care continuum among patients injured in regions remote from definitive trauma care. In another way, patients surviving to reach hospital and ultimately dying are more likely to do so in the ED in regions with limited access to trauma center care—they are less likely to move along the continuum long enough to receive care in the operating room or be admitted to hospital. These data suggest the potential value of interventions designed to enhance the skill set and resources in rural emergency departments or alternatively to assure that transportation assets are rapidly available for interfacility transfer.

The province of Ontario has an exclusive trauma system. The only level of trauma center designation is Level I,

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**Figure 1.** Timely access to trauma center care. Map of the province of Ontario, Canada. Trauma centers’ 1 hour land travel catchment areas are outlined. Dots represent census subdivision centroids.
and thus with the exception of these centers, there is no minimal standard of preparation or skills to assure the optimal preliminary care of the injured patient. Inclusive systems, where all centers participate in trauma care to the extent that their resources allow, provide lower levels of trauma center designation (i.e., Level III and IV) and are associated with a lower risk of injury-related mortality. This system configuration might have significant value in environments characterized by limited access to definitive trauma center care. Additionally, the availability and skill set of emergency physicians in rural environments is variable, with many physicians having very limited exposure to severely injured patients. Although preparation of physicians with ATLS has been shown to improve the process of preliminary care and subsequent outcomes, there is no requirement for ATLS certification in the region.

The population-based design of this analysis provides unique insights into where patients with severe injuries might be dying. Although our analyses might be confounded by lack of injury severity adjustment, the extent of confounding would have to be very high to account for the relatively high odds of death in ED with limited access to trauma center care. Apart from the potential for residual confounding, our study has other potential limitations. Although an increase in the risk of ED death was evident among those injured in moderately (1–50%) rural regions, no such effect was seen in the most rural environments. This finding might be related to survivor bias, with only the most robust (or least severely

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**Figure 2.** Trauma center access and injury mortality. Map of the province of Ontario, Canada. Trauma centers’ 1 hour land travel catchment areas are outlined. Census division age- and gender-adjusted injury mortality rates per 100,000 person-years are represented in a scale of grays.
injured) patients surviving to reach hospital in the face of extraordinarily long discovery or transport times.

Additionally, our GIS analysis modeled 1 hour land transport times, assuming that most patients were transported by land ambulance. There is no means to assess at the record level precisely how patients were transported. However, over the time interval of study, the majority of severely injured patients outside of major urban areas were first transported by land ambulance to a local facility, with interfacility transports often by air ambulance. It is therefore unlikely that this limitation would affect our findings. It is also plausible that differing policies toward the pronouncement of death in the field might account for the higher rates of “ED death” in rural areas, when in fact these patients are dead on arrival. It is difficult to assess precisely how this might affect our findings given the multiple EMS agencies involved and potential variation in regional policies. This limitation would bias toward an excess of ED deaths in rural areas only if these environments systematically had different policies than urban environments, which did not appear to be the case at the time of this study. Moreover, there is no reason to think that differences in access to ALS EMS services might account for the differences observed in location of death, because the type of prehospital care is not believed to modify outcome in trauma patients.21–23

Prehospital deaths were twice as likely in the most rural locations and in those with limited access to timely trauma center care. Hence, these findings emphasize the potential impact of prevention or reductions in discovery times through technologic innovations like automatic crash notification.24–30 However, the findings of a higher rate of ED deaths emphasize another point at which intervention might occur—in rural EDs or through increasing transportation assets to minimize time to interfacility transfer.27

Despite the limitations described, our approach offers several advantages compared with other studies focusing on rural trauma deaths.5,7,10 First, the source of data allows for a population-based analysis and provides a true estimate of how interventions directed toward prevention, pre-, or in-hospital care might affect rural trauma mortality. We also separate out the concepts of rurality and trauma center access using two distinct approaches. Although rural regions often have limited access to definitive trauma center care, this is not universally true and depends on geography, population density, and the definition of rural used for the analysis. With these advantages, this study provides new insights into rural trauma deaths and suggests the potential value of targeted interventions at the policy and provider level to identify opportunities for improving the delivery of preliminary trauma care in rural environments.

### REFERENCES


18. Utter GH, Maier RV, Rivara FP, Mock CN, Jurkovich GJ, Nathens AB. Inclusive trauma systems: do they improve triage or outcomes of 638

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**TABLE 3. Site of Death by Potential Access to Trauma Care Among Those Surviving to Reach Hospital**

<table>
<thead>
<tr>
<th>Location</th>
<th>All Deaths*</th>
<th>Rurality</th>
<th>Transport Times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 1609</td>
<td>&lt;1%, n = 818</td>
<td>1–50%, n = 691</td>
</tr>
<tr>
<td>ED</td>
<td>727 (45)</td>
<td>322 (39)</td>
<td>348 (50)</td>
</tr>
<tr>
<td>OR</td>
<td>127 (8)</td>
<td>85 (10)</td>
<td>94 (13)</td>
</tr>
<tr>
<td>Other in-hospital</td>
<td>755 (47)</td>
<td>411 (51)</td>
<td>307 (45)</td>
</tr>
</tbody>
</table>

* Includes deaths among those surviving to reach hospital.
the severely injured? J Trauma. 2006;60:529–535; discussion 535–537.