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Close to home: An analysis of the relationship between location of residence and location of injury

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Abstract

BACKGROUND—Injury surveillance is critical in identifying the need for targeted prevention initiatives. Understanding the geographic distribution of injuries facilitates matching prevention programs with the population most likely to benefit. At the population level, however, the geographic site of injury is rarely known, leading to the use of location of residence as a surrogate. To determine the accuracy of this approach, we evaluated the relationship between site of injury and of residence over a large geographic area.

METHODS—Data were derived from a population-based, pre-hospital registry of persons meeting triage criteria for major trauma. Patients dying at the scene or transported to hospital were

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Author Contributions

Dr. Haas contributed to the literature review, study design, data analysis, data interpretation, manuscript preparation and critical revision of the manuscript. Dr. Doumouras contributed to study design, data analysis, data interpretation and critical revision of the manuscript. Dr. Gomez contributed to study design, data analysis, data interpretation and critical revision of the manuscript. Dr. de Mestral contributed to study design, data interpretation and critical revision of the manuscript. Dr. Boyes contributed to study design, data analysis, data interpretation and critical revision of the manuscript. Dr. Morrison contributed to study design, data collection, data analysis, data interpretation and critical revision of the manuscript. Dr. Nathens contributed to study design, data analysis, data interpretation, manuscript preparation and critical revision of the manuscript.

included. Distance between locations of residence and of injury was calculated using geographic information system network analysis.

RESULTS—Among 3,280 patients (2005-2010), 88% were injured within 10 miles of home (median 0.2 miles). There were significant differences in distance between residence and location of injury based on mechanism of injury, age and hospital disposition. The large majority of injuries involving children, the elderly, pedestrians, cyclists, falls, and assaults occurred less than 10 miles from the patient's residence. Only 77% of MVC occurred within 10 miles of the patient's residence.

CONCLUSION—Though the majority of patients are injured less than 10 miles from their residence, the probability of injury occurring “close to home” depends on patient and injury characteristics.

LEVEL OF EVIDENCE—Epidemiological retrospective study. Level III.

Keywords

trauma systems; GIS

Background

Organized trauma systems, which integrate prehospital and acute care, lead to improved access to trauma care, and are associated with reduced patient mortality(1-3). Within trauma systems, institutional and transportation resources must be allocated in an efficient and equitable way, to assure timely access to trauma care for all injured patients. There has been a great deal of interest in using geospatial analyses to generate an improved understanding of injury epidemiology, and to identify areas where access to trauma center care is limited or inadequate(4-10). The overarching objective of such analyses has been to identify locations where injury prevention programs might be of greatest benefit, or areas where trauma center access must be improved.

In spite of their strengths, geospatial analyses have been limited by the availability of data regarding location of injury. To overcome this limitation, location of residence has often been used as a surrogate for the geographic coordinates of the site of injury(4, 5, 10-13). Accepting this surrogate, population-level access to trauma center care is calculated based on the proportion of patients having access to trauma care from their sites of residence. Such an approach therefore assumes that the majority of injuries occur “close to home”. There is, however, little data to support this assumption.

Given the importance of geospatial analyses to trauma system planning, establishing whether location of residence is a valid surrogate for location of injury is critical to trauma system quality improvement. In this study, our primary objective was to assess the relationship between location of injury and of residence among a diverse population of patients meeting trauma center triage criteria in a large geographic area.

Methods

Study design and setting

We performed a retrospective study that evaluated the distance between home (location of residence) and location of injury in a large cohort of patients meeting prehospital triage criteria for severe injury. This study was approved by the Research Ethics Board of St Michael's Hospital, Toronto.

Data source—Data for this study were derived from from the the Toronto site of the Resuscitation Outcomes Consortium (ROC) Epistry-Trauma dataset(14, 15). ROC Epistry-Trauma is a multi-site, population-based, North American prehospital epidemiologic dataset of injured persons originally developed by the ROC investigators to evaluate the relationship between prehospital care and outcome(14-16). The ROC Epistry trauma dataset consists of consecutively injured patients requiring activation of the emergency 9-1-1 system within the predefined geographic regions at each ROC site, and meeting specific field-based physiologic inclusion criteria for major trauma. Patients are included if they have a traumatic mechanism of injury and meet any of the predefined criteria at any point in the prehospital setting: systolic blood pressure ≤ 90 mmHg, respiratory rate < 10 or > 29, Glasgow Coma Scale score ≤ 12, intubation in the field or death in the field. These criteria are based on standard field trauma triage guidelines that have previously demonstrated high specificity for serious injury and need for specialized trauma resources among both adults and children(17).

This work utilizes the ROC Epistry-Trauma cohort from South-Central Ontario (the Toronto Regional RescuNET), an area extending from the Niagara Peninsula, north to Georgian Bay, and east to Peterborough, Ontario. Toronto Regional RescuNET encompasses a geographic region of over 6,000 square miles with a service population of over 6.6 million persons. Data are submitted from 8 EMS agencies representing rural, suburban, and urban providers and 32 destination hospitals. The region is served by three adult level I trauma centers and two pediatric level I trauma centers.

Selection of participants

Patients entered into the Toronto Regional RescuNET trauma data set between December 2005 and January 2011 were eligible for inclusion. As our objective was to examine the relationship between home and location of injury only among patients with severe injuries, patients who were assessed and not transported to the hospital were excluded. In addition, we excluded patients with non-mechanical causes of injury (drowning, suffocation, burns, environmental exposure, electrocution, poisoning, foreign body), as patients with these injuries are typically not included in geospatial analyses of trauma center access.

For each study subject, we used data available in the Toronto Regional RescuNET to identify patient information, including age, gender and mechanism of injury, scene disposition and hospital disposition. Patients were categorized based on age as children (age < 16), adults (age 16-64) or elderly (age ≥ 65). Hospital disposition was recorded only for patients transported to hospital. In addition, urban or non-urban location of residence was recorded for each patient. Urban location was defined as residence within a Census Metropolitan Area or a Census Agglomeration(18). A census metropolitan area (CMA) or a census agglomeration (CA) consists of municipalities centered on a large urban area. A CMA must have a total population of at least 100,000, of which 50,000 or more live in the urban core. A CA must have an urban core population of at least 10,000. All other locations were considered non-urban.

Patients' location of injury and location of residence were recorded. Location of injury was available in one of three formats: postal code, northing/easting or latitude/longitude. Location of residence was available in the form of a postal code, which is also the format commonly used in administrative databases. Patients that had missing location of residence or missing location of injury were excluded from analysis.

Geographic analysis

To derive a single set of spatial coordinates for each postal code, the Desktop Mapping Technologies Inc. (DMTI) Unique Enhanced Postal Code (UEP) file was used. This is a precision point file representing over 1 million postal codes across Canada and gives each postal code a unique set of geographic coordinates at the centroid of their geographical area. Road data were derived from a vector-based shapefile generated by DMTI, which represents Ontario's road system as a series of 634,746 line segments. Each segment contains information on addresses, spatial location, and road distances.

For each patient Euclidean distance ("as the crow flies" distance) was calculated from the scenes of injury to the home postal geographic coordinates derived from the UEP file. Euclidean distances were calculated with a point distance analysis tool. Map outputs were created using ArcGIS 9.3.

Statistical analysis

Medians and interquartile ranges were calculated for continuous variables and absolute and relative frequencies were measured for discrete variables. Frequencies were compared with the chi-square test. Medians were compared using the Mann-Whitney test or the Kruskal-Wallis test, as appropriate. Two-sided p values of < 0.05 were considered statistically significant. All statistical analyses were completed in SAS version 9.1 (Cary, NC).

Results

During the study period, 10,469 incidents meeting inclusion criteria were recorded in the Toronto Regional RescuNET. Among these patients, 1,776 (17.0%) incidents were missing a location of residence, 112 (1.1%) were missing a location of injury and 67 (0.6%) were missing both; these patients were excluded from analysis. A further 213 records (2.1%) had non-valid or non-Ontario postal codes for location of residence and 38 records (0.3%) had non-valid entries for location of injury. Distance between location of residence and location of injury was therefore calculated for 8,263 patients (78.9%). The 2,206 patients excluded from the study, as compared to those who were included in the final analysis (n = 8,263), were significantly more likely ($p< 0.01$) to be non-elderly adults (63.5%, n = 1,401 vs. 52.0%, n = 4,298), male (69.1%, n = 1,525 vs. 57.7%, n = 4,767), involved in a traffic incident (34.5%, n = 762 vs. 19.9%, n = 1,644) and to have died at the scene of injury (35.1%, n = 774 vs. 5.3%, n = 438).

Patients in the final cohort (n = 8,263) were predominantly non-elderly males (Table 1); the most common mechanism of injury in the study was falls (53.2%), followed by traffic incidents (19.9%). Among falls, 3,099 (70.5%) were same level falls, and 1,298 (29.5%) were falls from height. Among traffic incidents, 1,110 (67.6%) involved patients injured in car or motorcycle collisions, 374 (22.8%) involved pedestrians injured by a vehicle and 159 (9.7%) involved injured cyclists. 7,946 (96.2%) of patients had a location of residence in an urban location.

In 88% of cases (n = 7,268), patients were injured within 10 miles of their location of residence (Table 1). 3,591 patients (42.6%) were injured at their location of residence. The proportion of injuries occurring at home differed significantly across age groups and mechanisms of injury. Almost two thirds of elderly individuals (n = 1,614) and almost half of children (n = 648) were injured at their location of residence, compared to only 28.8% (n = 1,237) of non-elderly adults ($p < 0.001$). Falls (57.4%, n = 2,523), gunshot wounds (46.9%, n = 90) and stab wounds (41.8%, n = 117) were significantly more likely to occur at the location of residence compared to traffic incidents (8.6%, n = 141) ($p < 0.001$).

The median distance between location of residence and location of injury was 0.2 miles (IQR 0-3.5 miles). There were statistically significant differences in the median distance between location of residence and of injury based on gender, age, mechanism of injury, and hospital disposition (Table 2). Specifically, non-elderly adults and those injured in traffic incidents were likely to be injured further from home. However, even in groups where distances between home and location of injury were statistically higher, the 75^{th} percentile of distances remained under 10 miles (6.2 miles for incidents involving non-elderly adults, 9.2 miles for traffic incidents).

We further analyzed the subgroup of traffic incidents (Table 3). The median distance between home and the location of injury for car or motorcycle crashes was 4.6 miles (IQR 1.4-11.5). Incidents involving injured pedestrians or cyclists were likely to occur very close to home. The median distance between location of residence and location of injury for injured pedestrians was 1.1 miles (IQR 0.2-4.5), and 1.2 miles (IQR 0.4-2.7) for injured cyclists. Finally, we analyzed the distance between location of residence and location of injury among patients who died of their injuries after being involved in traffic incidents, either at the scene or in-hospital. The median distance to the location of injury among individuals involved in a fatal car or motorcycle collision was 5.5 miles (IQR 1.4-16.6). There was no significant difference in the distance from home when comparing fatal and non-fatal incidents traffic incidents.

Discussion

Trauma system resources are limited, and must be distributed in an efficient and equitable fashion. Ideally, prevention efforts should be targeted towards individuals at highest risk for injury, and human and physical resources should be allocated to ensure adequate access to care to the greatest number of patients. In order to aid decision making regarding prevention and trauma system planning efforts, numerous authors have used geospatial analyses to identify geographic areas where resources are inadequate, or where individuals are at increased risk of injury or adverse outcomes.

Evaluating access to trauma center care has been one of the main applications of geospatial analyses of trauma, both in Canada and in the United States(4-6, 10, 13, 19, 20). Such analyses map trauma center catchment areas to identify populations that lack physical access to a trauma center within a reasonable timeframe; population data for such analyses have frequently been derived from census data(4, 5, 13, 19). These analyses provide estimates of the proportion of the population that lacks access to trauma center care. However, a central assumption of such analyses is that the distribution of the locations of injuries requiring care at a trauma center closely follows the distribution of the population as a whole. The evidence to support this premise has been limited.

In this study, we used a population-based sample of patients at high risk of severe injury, based on evidence-based prehospital triage criteria(17). We demonstrated that 88% of patients were injured within 10 miles of home, with approximately 40% of injuries occurring at the place of residence. Although there were significant variations in the distance between location of residence and location of injury across age group and across mechanisms of injury, even those injuries least likely to occur “close to home” predominantly occurred within short distances of patients’ location of residence. We demonstrate that three quarters of motor vehicle collisions in which patients met triage criteria for trauma center transport occurred within 10 miles of patients’ homes, and half of all fatal collisions involving vehicles occur within 5.5 miles of victims’ location of residence. These data have important implications not only for planning of trauma system resource allocation, but also for injury prevention strategies and programs.

Our study had a number of strengths. Patients injured due to any mechanical cause of injury were included, and our data source allowed us to identify both patients who died and those who survived their injuries. In addition, we had precise geographic coordinates both for the site of injury and for the patients’ location of residence, allowing us to evaluate the distance between these locations with high precision using GIS methods. Finally, our patient population was drawn from a wide geographic area, including multiple urban, suburban and rural areas.

Several other authors have attempted to evaluate the relationship between location of residence and location of injury; these previous data, though congruent with our findings, were of more limited scope. Multiple studies have focused on the location of injury among children. Several studies have examined the relationship between location of injury and location of residence in pediatric pedestrian injuries within a single urban area(21-23); these reports suggest that children are likely to be injured within a short distance of their homes. In a larger study, Nagaraja and colleagues examined injury-related deaths among children across the United States; these authors report that over half of injury-related pediatric deaths occurred in the home environment(24). However, deaths related to motor vehicle collisions and intentional injuries were not included in the analysis, nor were non-fatal injuries.

Finally, a national analysis of ED visits demonstrated that 39% of injury-related ED visits and 51% of all unintentional injury visits among pediatric patients were for injuries that occurred at home(25). A recent, single center study of adult pedestrian injuries also demonstrated that such injuries occur in close proximity to patients' locations of residence, with a median distance of only 1.4 km(26).

In 2007, NHSTA conducted a national survey regarding the prevalence of injuries secondary to motor vehicle collisions and regarding restraint use(27). Location of injury, as related to location of residence, was addressed within the survey. Approximately one quarter of respondents had been involved in a motor vehicle collision in their lifetime, and half of collisions were reported to have occurred within 5 miles of the respondent's home. Clearly, however, these findings capture only patients surviving their motor vehicle collisions, include patients with minor injuries, and represent only self-reported estimates of distance.

More recently, Myers and colleagues published an analysis of the relationship between county of residence and county of injury across the United States, using the county listed on patients' death certificates as a proxy for county of injury(28). The authors found that county of residence matched county of death in approximately three quarters of cases, and that 88% of individuals died in their home county or a contiguous county. This analysis has some clear limitations. In addition to focusing exclusively on patients who died of their injuries, the authors could not provide estimates of geographic distance. In addition, the assumption that patients are treated in (and therefore die) in the county in which the injury occurred may not be accurate.

Our study also has several limitations. Twenty-one percent of patients in our cohort were missing information necessary to calculate the relationship between location of residence and location of injury. Patients with missing data (location of residence in the vast majority of cases) were more likely to be non-elderly adults involved in motor vehicle collisions and who died at the scene. Clearly, these are patients where EMS personnel may have had limited involvement in care, and may therefore have led to incomplete data collection. Lack of a home address (homelessness) may have also been a factor in our population. In addition, although all patients meeting criteria for triage to a trauma center were captured in the study, our dataset did not include information about the degree of injury severity in our patient population. It is possible that our patient population includes a large number of patients with non-severe injuries. This is unlikely, however. We captured all scene deaths (5% of our study population). Moreover, 11% of patients arriving to hospital alive died, suggesting a high degree of injury severity.

In summary, our data support the assumption that the majority of severe injuries occur close to home. Although the relationship between location of injury and location of residence varies based on age and mechanism of injury, these two geographic locations are nevertheless closely related for the majority of patients with injuries meeting trauma triage criteria, regardless of age or mechanism of injury. While geospatial analyses of injury based on small geographic units (neighborhoods) will continue to be dependent on data regarding the precise location of injury, geospatial analyses of the epidemiology of trauma based on county or other large geographic units can reliably use location of residence as a proxy for location of injury.

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Table 1

Patient and injury characteristics, as related to distance between location of residence and location of injury

	Proportion of patients	Proportion of patients injured within specified distance of residence		
		≤ 10 miles	≤ 20 miles	≤ 30 miles
Overall (n, %)	8,263 (100)	7,268 (88.0)	7,744 (93.7)	7,922 (95.8)
Gender (n, %)				
Female	3,489 (42.2)	3,130 (89.7)	3,305 (94.7)	3,364 (96.4)
Male	4,767 (57.7)	4,132 (86.7)	4,432 (93.0	4,451 (95.5)
Age (n, %)				
Adult	4,298 (52.0)	3,547 (82.5)	3,918 (91.2)	4,055 (94.3)
Elderly (age ≥ 65)	2,530 (30.6)	2,425 (95.8)	2,463 (97.3)	2,481 (98.1)
Children (age < 16)	1,402 (17.0)	1,264 (90.2)	1,330 (94.9)	1,353 (96.5)
Mechanism of injury (n, %)				
Fall	4,397 (53.2)	4,096 (93.1)	4,241 (96.4)	4,293 (97.6)
Traffic incident*	1,644 (19.9)	1,267 (77.1)	1,441 (87.6)	1,515 (92.1)
Other blunt	778 (9.42)	599 (77.0)	693 (89.1)	721 (92.7)
Other injury	749 (9.1)	671 (89.6)	702 (93.7)	715 (95.5)
Stab wound	280 (3.4)	263 (93.9)	272 (97.1)	278 (99.3)
Gunshot wound	192 (2.3)	167 (87.0)	182 (94.8)	184 (95.8)
Missing	223 (2.7)	205 (91.9)	213 (95.5)	216 (96.9)
Scene disposition (n, %)				
Alive	7,824 (94.7	6,899 (88.2)	7,353 (94.0)	7,518 (96.1)
Dead	438 (5.3)	369 (84.2)	391 (89.3)	404 (92.2)
Hospital disposition (n, %)**				
Alive	6,735 (86.1)	5,938 (88.2)	6,330 (94.0)	6,472 (96.1)
Dead	841 (10.7)	736 (87.5)	790 (93.4)	808 (96.1)

*Traffic incident – incident involving a motor or other vehicle

**Hospital disposition was recorded only among patients with a scene disposition of “Alive”.

Table 2

Median distance in miles between location of residence and location of injury by patient and injury group

	Distance between location of residence and location of injury		
	N	Median (IQR)	P value
Gender			<0.001
Female	3,489	0.0 (0.0-2.5)	
Male	4,767	0.5 (0.0-4.2)	
Age group			<0.001
Adult	4,298	1.3 (0.0-6.2)	
Elderly (age ≥ 65)	2,530	0.0 (0.0-0.2)	
Children (age < 16)	1,402	0.1 (0.0-2.3)	
Mechanism of injury			<0.001
Fall	4,397	0.0 (0.0-1.1)	
Traffic incident*	1,644	2.9 (0.7-9.2)	
Other blunt	778	2.2 (0.1-9.2)	
Other injury	749	0.1 (0.0-2.0)	
Stab wound	280	0.1 (0.0-2.8)	
Gunshot wound	192	0.1 (0.0-3.5)	
Missing	223	0.0 (0.0-2.0)	
Scene disposition			0.299
Alive	7,824	0.2 (0.0-3.4)	
Dead	438	0.0 (0.0-4.5)	
Hospital disposition**			0.012
Alive	6,735	0.2 (0.0-3.5)	
Dead	841	0.1 (0.0-3.5)	

*Traffic incident – incident involving a motor or other vehicle

**Hospital disposition was recorded only among patients with a scene disposition of “Alive”.

Table 3

Median distance in miles between location of residence and location of injury by category of traffic incident and patient outcome

	All		Fatal		Non-fatal		p value
	N	**Median (IQR)**	**N**	**Median (IQR)**	**N**	**Median (IQR)**	
Bicycle	159	1.2 (0.4-2.7)	6	0.4 (0.3-0.6)	153	1.2 (0.5-2.8)	0.115
Car/motorcycle	1,110	4.6 (1.4-11.5)	263	5.5 (1.4-16.6)	847	4.4 (1.4-10.7)	0.117
Pedestrian	374	1.1 (0.2-4.5)	110	1.6 (0.4-4.9)	264	0.8 (0.2-4.1)	0.163