Health & Place 19 (2013) 131–137

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Evaluating potential spatial access to trauma center care by severely injured patients

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ARTICLE INFO

Article history:
Received 15 June 2012
Received in revised form
22 October 2012
Accepted 26 October 2012
Available online 10 November 2012

Keywords:
Spatial access
Geographic information system
Severe injury
Trauma systems
Rural

ABSTRACT

Injuries are a major public health problem around the world. Previous research has suggested that providing prompt access to specialized trauma center care may greatly improve the health outcomes of trauma patients. In this paper, a geographic information system (GIS) method is used to examine potential spatial access to trauma centers by individuals who were either hospitalized or died as a result of a major trauma. Overall, it was determined that 68.5% of individuals who suffered from a major trauma lived within one hour travel time of a Level I or II trauma center. In addition, major traumas resulting in death were found to have poorer potential spatial access to trauma center care than those that were admitted to hospital.

1. Introduction

Injury is a significant source of premature mortality, hospitalizations, and health care expenditure around the world. Globally, 5.8 million people die every year as a result of an injury and millions more are hospitalized (World Health Organization, 2010). Although the overall death rate from injury has declined in Canada over the past decade, it remains alarmingly high at 42.06 per 100,000 and each year the total direct and indirect costs of injuries amount to an estimated $19.8 billion (SMARTRISK, 2009). Although injury prevention strategies play an important role in reducing the rate of injuries, the care patients receive after an injury has occurred can dramatically affect their chances of survival (Liberman et al., 2005; MacKenzie et al., 2006). Unfortunately, poor spatial access to trauma center care may be leading to potentially preventable injury-related mortality and morbidity in Canada.

While previous research has focused on measuring spatial access to trauma center care by the general population (Branas et al., 2005; Hameed et al., 2010), the work presented in this paper is unique in that it evaluates spatial access to trauma center care by individuals who have sustained a major trauma. In other words, this approach acknowledges that the spatial distribution of injury may not parallel the spatial distribution of the general population, which is a reasonable assumption given that not all population groups have the same risk of severe injury (Charyk-Stewart et al., 2010; Cubbin and Smith, 2002; Laupland et al., 2005; Pickett et al., 1997).

In this paper we begin by outlining the rationale for trauma center care and then provide a brief description of trauma services in Canada. Next, we use hospitalization and mortality data to identify major traumas and then use geographic information systems (GIS) to measure their potential spatial accessibility to trauma center care. More specifically, we determine what proportion of the population that sustained a major trauma between 2001 and 2006 lived within one hour drive time of either a Level I or II trauma center. After presenting the results, which conflict with previous research, we conclude by discussing the implications of our findings.

2. Rationale for trauma center care

Although one half of all injury-related deaths occur at the site of the injury, the remaining 50% of deaths are potentially preventable through prompt access to appropriate medical care (Meislin et al., 1997; Rogers et al., 2005). Ideally, care of the severely injured should be provided in a designated trauma center that has undergone accreditation or verification by an external agency (Committee on Trauma, 2006; Trauma Association of Canada, 2011). Designated trauma centers are acute care hospitals that have a trauma team

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http://dx.doi.org/10.1016/j.healthplace.2012.10.011

immediately available to assess patients, and all the resources required to provide definitive care to severely injured patients (Committee on Trauma, 2006; Trauma Association of Canada, 2011). Access to a trauma center is critically important for the severely injured patient, as care in this environment is associated with a 25% lower risk of death compared to care in non-designated centers (Liberman et al., 2005; MacKenzie et al., 2006).

3. Trauma center care in Canada

Because the provision of health care services is a provincial responsibility in Canada, trauma services have been implemented differently across provinces. These differences are the result of many factors, including varying operational budgets and structural organizations in each provincial health care system. For example, some provinces have multiple regional health authorities (e.g., British Columbia), whereas others are more centralized (e.g., Alberta). Canada's provinces also differ dramatically in terms of their physical landscape and overall size—making the delivery of trauma care much more challenging in some provinces than in others. The spatial distribution of the population within each province also has considerable impact on the provision of trauma services.

Overall, however, trauma system development in Canada is in its early stages. Although a few provinces have relatively mature trauma systems that optimize access to trauma center care, many provincial trauma systems are still missing essential components. For example, the majority of provinces and territories (all except British Columbia, Alberta, Ontario, and Nova Scotia) have yet to implement pre-hospital air transportation programs (Hameed et al., 2010). For a more detailed description of Canada's provincial and territorial trauma systems please refer to Hameed et al. (2010).

4. Data

4.1. Trauma centers

Since the majority of trauma centers in Canada have yet to be accredited or verified by an external agency, a national survey of trauma center personnel was used to identify all Level I and II trauma centers across Canada, regardless of their designation status. The survey used the Trauma Association of Canada (2011)Trauma System Accreditation Guidelines to categorize hospitals based on the resources they provide as well as other characteristics such as patient volume and training (Hameed et al., 2010). Because the purpose of this study was to measure access to expert care within resource-rich facilities by patients with life threatening injuries, only Level I and II trauma centers with full time neurosurgical capability were included. The neurosurgical requirement was used because Traumatic Brain Injury (TBI) is the most common cause of traumatic mortality and because TBI patients who are transferred directly to a trauma center capable of providing neurosurgical care have a much higher survival rate than those who are sent to centers without neurosurgical capacity (Hameed et al., 2010; Härtl et al., 2006). Once these hospitals were identified, their street addresses were geocoded using road network data from Desktop Mapping Technologies Inc. (DMTI) Spatial Canada v.2009.3.

4.2. Major traumas

Both Vital Statistics and Hospital Morbidity Database data were used to identify all major traumas that occurred between April 1, 2001 and March 31, 2006. A major trauma was defined as an injury that results in death prior to hospital admission or one that is assessed at a hospital and given an Injury Severity Score (ISS) greater than 15. ISS, the most frequently used method for quantifying injury severity, is derived from the Abbreviated Injury Scale, which provides an injury severity score ranging from one to six for each injury across all body regions (Association for the Advancement of Automative Medicine, 1998; Baker et al., 1974). Patients less than 16 years of age were excluded because severely injured children are often treated at pediatric trauma centers, which were not the focus of this study (Carr and Nance, 2010). Since cases were mapped using their full six digit postal codes and the province of Quebec only reports the forward sortation areas (i.e., the first three digits of the postal code) of patients who are hospitalized, Quebec was excluded from this study. All of the preliminary data preparation and extraction was conducted using SAS v.9.1 (SAS Institute, 2004).

4.2.1. Major traumas resulting in death prior to hospitalization

Major traumas that resulted in death outside of hospital were identified through Canada's Vital Statistics Death Database using the cause of death field.

4.2.2. Major traumas resulting in hospitalization

Major traumas that resulted in a hospitalization were identified through the Hospital Morbidity Database (HMBD), a national administrative discharge database containing demographic, administrative and clinical data on all inpatient hospitalizations in Canada. Health Person-Oriented Information (HPOI) was derived from the HMBD at Statistics Canada in order to link these records at the person level. HPOI includes information on the patient's age, sex, medical diagnoses, admission/discharge dates, and postal code of home residence. A recently developed and validated algorithm developed by Haas et al. (2012) was then used to derive ISS from the cases with injury-related (i.e., S00 to T79.0) International Classification of Diseases, 10th Revision (ICD-10) diagnoses codes. Injuries related to foreign bodies (T15–T19), burns and corrosion injury (T20–T32), poisoning (T36–T65), and environmental exposure (T33–T35, T66–T78), as well as those injuries resulting from medical complications and the late effects of injury (T80–T98) were excluded from our analysis.

Since Canada's provinces and territories transitioned from the ICD-9 to the ICD-10 at different times, this study was only able to use a full five years (2001/2002–2005/2006) of data for British Columbia, Newfoundland, Prince Edward Island, Nova Scotia, and the Yukon. As for the remaining provinces and territories, four years of data (2002/2003–2005/2006) was used for Alberta, Ontario, Saskatchewan, and the North West Territories, three years (2003/2004–2005/2006) for New Brunswick and Nunavut, and two years (2004/2005–2005/2006) for Manitoba. For consistency, these same date ranges were used when extracting injuries from the Vital Statistics database. To eliminate the double counting of patients who were transferred from one hospital to another for the same major trauma event, an individual discharged and admitted on the same day was considered a transfer, and only the initial hospitalization record was retained for our analysis (Oliver and Kohen, 2009).

5. Methods

5.1. Mapping major traumas

Individuals who sustained a major trauma were mapped according to their six-digit postal code of home residence using the geographic coordinates provided in Statistics Canada (2007)

Postal Code Conversion File. We used the postal code of home residence instead of the location of the injury because the latter was not included in either of the datasets used in this study. Although the average postal code in Canada contains 19 households, the size of a postal code can vary dramatically from urban regions where one postal code may serve a single business (i.e., zero households), to rural and remote regions where a postal code may contain up to 10,000 households (Statistics Canada, 2007. All mapping and spatial analyzes were conducted using ArcGIS Desktop v.10 (ESRI, 2010).

5.2. Calculating travel times

The Origin-Destination (OD) Cost Matrix tool available in ArcGIS's Network Analyst toolbox was used to determine the proportion of major trauma cases within one hour travel time of a Level I or Level II trauma center. Travel times were also calculated for two mutually exclusive subpopulations – major traumas resulting in death prior to hospital admission and major traumas resulting in a hospitalization – because of their suspected differences in spatial access to trauma center care. In the context of this study, "cost" refers to the time it takes an individual suffering from a major trauma to be transported by land from their home residence to a trauma center. Using the home residences as "origins" and the trauma centers as "destinations", this tool generates a table giving the total travel time in minutes from each home resident postal code to the nearest trauma center. The GIS calculates these total travel times by summing the individual drive times associated with each road segment that make up the quickest route between each trauma location (i.e., postal code) and a trauma center. The individual drive times associated with each road segment were derived from the posted speed limits and road segment lengths, which are stored as attribute values in the road network data. Using posted speed limits to model ambulance drive times is appropriate given that ambulances normally obey these limits when transporting patients to ensure patient safety and avoid causing secondary motor vehicle collisions (Amram et al., 2011). If a trauma postal code was farther than 2500 m from the closest road segment, it was assumed to be farther than four hours from the nearest trauma center. In order to account for the cross-border care of patients, trauma centers located in the neighboring provinces were included as possible destinations in all drive time calculations. If there were fewer than 10 major trauma cases per provincial drive time category (e.g., within one hour or farther than one hour), these cases were suppressed to ensure patient confidentiality.

6. Results

A total of 32 Level I and II trauma centers capable of providing definitive trauma care were identified, all of which were located in urban centers near the southern border of the country. Although each of them had provincial designation, only 18 (56%) had been accredited or verified by an external agency, such as the TAC (Hameed et al., 2010). Prince Edward Island, Canada's smallest province, and Canada's three northern territories (the Yukon, North West Territories, and Nunavut) did not contain any Level I or II trauma centers. Thus, assuming all major traumas were treated at a trauma center, 827 (1.3%) of the trauma cases identified in this study would have had to travel outside their resident province or territory to receive the recommended care.

During the study period, 65,004 major traumas were identified. Of these, 13,410 (20.6%) resulted in death prior to hospital admission and 51,594 (79.4%) resulted in a hospitalization. However, 1866 cases (2.9% of the dataset) were excluded from our analysis because they did not have a corresponding postal code in Statistics Canada's Postal Code Conversion file, they had to be suppressed to ensure patient confidentiality, or their postal code was not connected to a trauma center by the road network (i.e., the postal code was located on an isolated portion of the road network such as an island, or a portion of the road network that was incompletely or incorrectly digitized). Once these cases were removed, we were left with 63,138 major traumas for our analysis, of which 13,103 (20.8%) resulted in death and 50,035 (79.2%) resulted in a hospitalization.

Overall, 68.5% of the major trauma cases identified in this study lived within one hour travel time of either a Level I or II trauma center. However, as shown in Table 1, spatial access to trauma center care varied across the country, with some provinces having better access to trauma center care than others. Ontario had the best coverage with 79.9% of major trauma cases living within one hour of either a Level I or II trauma center. Prince Edward Island and Canada's three territories, which have no trauma centers of their own and fall outside the one hour catchment areas of their neighboring provinces' trauma centers, had the worst coverage, with no severe injuries occurring within one hour drive time of either a Level I or II center.

Major traumas that resulted in death prior to hospital admission had poorer (62.4%) potential spatial access to trauma center care than the major trauma cases who survived to hospital admission (70.0%). As shown in Fig. 1, this difference was consistent across all the provinces except in New Brunswick, where the estimates of spatial accessibility were almost identical (42.9% vs. 42.0%).

7. Limitations

This observational study has several recognized limitations. First, because the precise geographic coordinates of the actual sites of major trauma were not present in either of the datasets used in this study, the home residence postal codes were used as a proxy measure. This is reasonable given that most injuries occur within a relatively short distance (e.g., 5–10 miles) of the home (Boyle et al., 2007; Evans et al., 2005). However, it is possible that the use of postal codes caused us to overestimate spatial accessibility to trauma center care in Canada because severe injuries, such as those resulting from motor vehicle collisions, often occur

Table 1
The number and percent of major trauma cases living within one hour of a Level I or II trauma center, by health outcome and province.

Province/Territory	Major traumas resulting in death outside a hospital		Major traumas resulting in a hospitalization		Total (all major traumas)	
	#	%	#	%	#	%
Alberta	1089	52.9	5702	64.6	6791	62.4
British Columbia	2327	67.3	8776	73.9	11,103	72.4
Manitoba	177	52.5	796	63.4	973	61.1
New Brunswick	196	42.9	488	42.0	684	42.3
Newfoundland	97	29.0	260	36.3	357	34.0
Nova Scotia	259	39.3	838	41.8	1097	41.2
Ontario	3653	78.1	16,796	80.3	20,449	79.9
Saskatchewan	383	42.7	1382	51.3	1765	49.2
Canada[a,b]	**8181**	**62.4**	**35,038**	**70.0**	43,219	**68.5**

[a] Prince Edward Island and Canada's northern territories are not shown because they have no trauma centers of their own and are farther than one hour drive time from their neighboring provinces' trauma centers. However, they were used to calculate the national estimates.

[b] The national figures exclude Quebec.

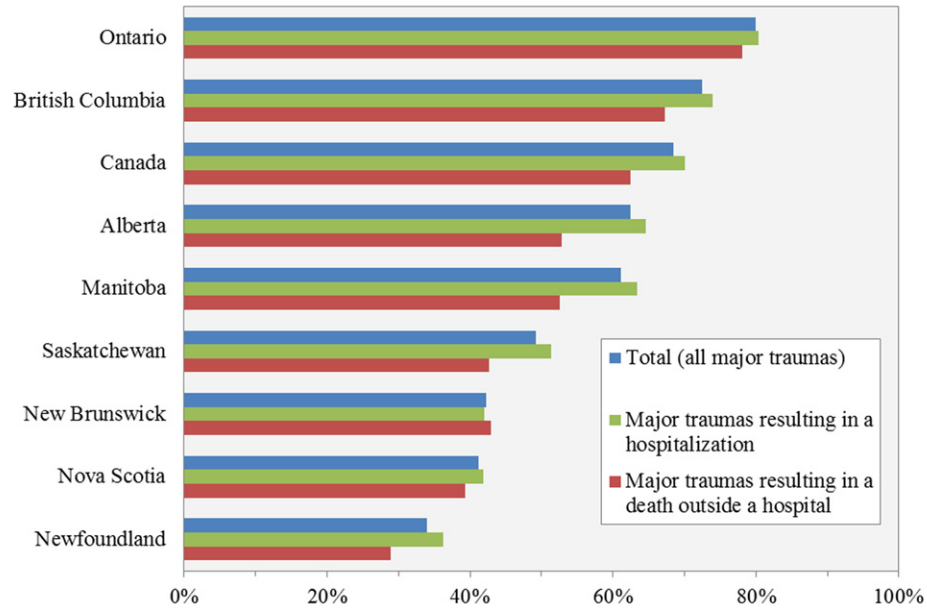

Fig. 1. Percentage of major trauma cases that lived within one hour of a Level I or II trauma center, by health outcome and province. Prince Edward Island and Canada's northern territories are not shown because they have no trauma centers of their own and are farther than one hour drive time from their neighboring provinces' trauma centers. However, they were used to calculate the national estimates. Also note that the national figures exclude Quebec.

in rural or remote regions of the country far from any residential neighborhood (Muelleman et al., 2007; Peek-Asa et al., 2004). It is also important to note that postal codes typically cover large geographic areas in rural regions of the country and thus, using postal code centroids as a proxy for home address is more accurate in urban versus rural settings.

A second limitation was our inability to accurately account for any additional travel time caused by traffic lights, stop signs, traffic congestion, road closures, or poor weather conditions. Because the datasets used in this study did not contain information about how the cases were transported to hospital, we were also unable to account for the time EMS personnel spend traveling to and at the scene of the trauma for instances when individuals are transported via air or ground ambulance. This too may have caused us to overestimate spatial accessibility of trauma services. However, when the estimated drive times were compared with a random sample of actual ambulance drive times from Metro Vancouver, British Columbia, the results were comparable. We were also unable to account for the availability of pre-hospital air transportation, which may have caused us to underestimate access to trauma center care in the provinces where these programs exist. However, depending on the additional time required to prepare the air ambulance and the proximity of the closest helipad or landing zone to the scene of the trauma, air transport may not be faster than ground transportation (Hameed et al., 2010; Lerner et al., 1999; Shepherd et al., 2008).

Our study was also unable to discern why severe injuries resulting in death had poorer spatial access to trauma center care than those resulting in a hospitalization. It may mean that poor spatial access to trauma center care increased the risk of death, but it is more likely a reflection of the fact that the rate of severe injury is higher in rural and remotes regions of the country. Thus, more research is needed to determine the underlying causal mechanisms behind this identified correlation.

Our study also has limitations related to the two datasets that were used. Because in-hospital deaths were recorded in both the hospitalization and Vital Statistics data, we had to exclude them from the Vital Statistics data in order to avoid the double counting of cases. This may have caused us to exclude traumas that resulted in an in-hospital death. For example, falls and gunshot wounds classified as not severe (i.e., ISS <16), but that resulted in an in-hospital death would have been excluded from our analysis. Since the Vital Statistics data often includes only one cause of death code, we may have also excluded trauma-related deaths where the primary cause was recorded as something other than a trauma. In addition, our method of using admission and discharge by date to remove duplicate hospitalization records, which is standard practice with these data, may have resulted in the double counting of cases that took longer than one day to transfer.

Lastly, our methods and the interpretation of our results are based on the assumption that the future spatial distribution of need for trauma center care will closely match that of the past. Although extrapolating past patterns into the future is risky, it is often the only option when planning the future allocation of resources and is common practice in the health care services literature (Branas et al., 2000; Foo et al., 2010; Schuurman et al., 2009). Nonetheless, caution should be taken when interpreting our results, especially for those provinces where only a few years of data were aggregated.

8. Discussion

The proportion of major trauma cases that lived within one hour of the nearest trauma center was highlighted in this paper because one hour, or the "golden hour", is widely recognized as the time within which patients should receive emergency medical care at a hospital in order to minimize the risk of serious health outcomes (Crews and Holbrock, 2005; Raghavan and Marik, 2006). The principle of the golden hour was originally based on data collected during World War I, which showed that the time to treatment had a significant impact on the mortality rates of injured soldiers (Kane et al., 2007). Although one hour travel time is frequently used by researchers when evaluating spatial accessibility to health services (Brabyn and Skelly, 2002; Schuurman et al., 2006), it has also been criticized because of the inherent differences (e.g., type of injury, age, gender) between the soldiers who are injured in combat and the civilians who are injured on home soil (Lerner and Moscati, 2001). Nonetheless, there is ample evidence to suggest that the treatment patients receive during the first few hours, or the "golden hours", following a major trauma is paramount to their survival (Raghavan and Marik, 2006; Sampalis et al., 1999).

While need for trauma center care has typically been estimated through an assessment of the number and distribution of severely injured patients admitted to hospital, this information provides a biased evaluation (Nathens et al., 2004b). Focusing on this cohort alone results in the exclusion of individuals who die in the field or the emergency department, whose location of death may well reflect an unmet need for trauma center care. Others have focused on the relationship between the underlying population distribution and the location of trauma centers as a measure of access, but this too is a poor surrogate of need given that not all populations are at similar risk of major trauma (Branas et al., 2005; Hameed et al., 2010; Nance et al., 2009). For example, Aboriginal Canadians are at much higher risk of major trauma than the general population (Karmali et al., 2005).

Our analysis improved upon this earlier work in two important ways. First, the use of multiple datasets, which account for both the major trauma cases that die before reaching a hospital as well as those admitted to hospital, eliminates the potential for survival bias. In fact, to the best of our knowledge, this is the first Canadian study that combined hospitalization and mortality data to examine the entire spectrum of major trauma cases. Second, the use of these datasets allowed us to evaluate potential spatial access to trauma center in Canada by those individuals who had sustained a major trauma (i.e., the target population) instead of the general population. In other words, these improvements enabled us to provide better insight into how well Canada's trauma care needs and resources are spatially aligned.

Our analysis showed that major traumas resulting in death had poorer potential spatial access to trauma center care than those that were admitted to hospital. However, because of our study design we are unable to determine whether this association is casual or whether it is due to a confounding factor. For instance, this result may simply indicate that traumas sustained by individuals who live farther from trauma center care are due to a different, and perhaps more fatal mechanism. It may also be due to the fact that postal codes have less positional accuracy in rural versus urban regions. Further research is therefore needed to determine whether spatial access to trauma center care effects a severely injured patient's chances of survival, as has been suggested in the trauma literature (Fatovich and Jacobs, 2009; Gomez et al., 2010; Kroneman et al., 2010; Minei et al., 2010; Muelleman et al., 2007; Peek-Asa et al., 2004).

Although 68.5% of the major trauma cases identified in this study lived within one hour travel time of a Level I or II trauma center, the results varied from province to province. The spatial distribution of the population relative to the location of the trauma centers may explain some of these differences. For example, Newfoundland, which had the worst coverage, only has one trauma center that is located at its eastern edge whereas Ontario, which had the best coverage, has seven trauma centers that are well aligned with the major population centers along its southern border. Interestingly, the larger provinces (e.g., Ontario, British Columbia) have the best coverage and the smaller ones (e.g., Nova Scotia, New Brunswick) have some of the worst coverage. A potential explanation for this could be that in these smaller provinces the difference between the rate of severe injury in the rural and remote regions and the urban centers, where the trauma centers are located, is more exaggerated.

As shown in Fig. 2, the results of this study are inconsistent with previous work by Hameed et al.(2010), who estimated potential spatial access to trauma center care in Canada using a very similar drive time method. However, instead of using the spatial distribution of severely injured patients to estimate the

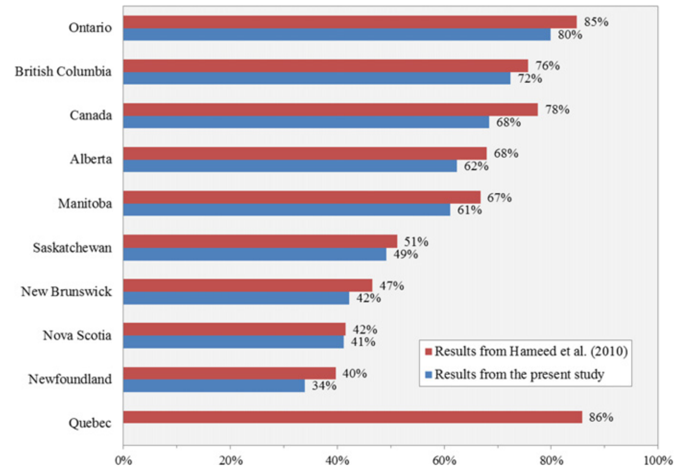

Fig. 2. The comparison of two estimates of potential spatial access to trauma center care in Canada, by province. The results of the present study are shown alongside the results of a previous study conducted by Hameed et al. (2010). Both give an estimate of proportion of the population within one hour of a Level I or II trauma center. However, the present study used the postal codes of severely injured patients to estimate the need for trauma center care whereas the previously published findings were derived using 2006 census block population figures.

need for trauma center care, the authors of this paper based their analysis on census block populations. Although the inclusion of Quebec may explain their higher national estimate of spatial accessibility to trauma center care, the conflicting provincial results suggest that the distribution of major trauma does not parallel that of the general population. These differing results, therefore, highlight the importance of using a target population that accurately reflects the spatial distribution of need when estimating potential spatial access to a particular health care or social service.

Also shown in Fig. 2, the estimates from the two studies were quite different for some provinces and not very different for others. In the provinces with similar results, the spatial distribution of the general population is likely very comparable with the spatial distribution of the severely injured population. On the other hand, in the provinces where the estimates are dissimilar, the spatial distribution of the general population and that of the severely injured population is probably very different.

In comparison to the proportion of the US population living within one hour of a Level I or II trauma center (84.1%) reported by Branas et al. (2005), the results of this study indicate that most of Canada's provinces have poorer potential spatial access to trauma center care than their American neighbors. However, their analysis accounted for the availability of helicopter as well as ground ambulance transportation of patients, which increased the overall level of access from only 56.4%–84.1%. Thus, when only considering ground transportation of patients, our findings suggest that most of Canada's provinces have better potential spatial access to trauma center care than the US. In addition, because Branas et al. (2005) based their estimates on census block group populations instead of the actual population of severely injured patients, they may also have overestimated access to trauma center care.

According to the Canada Health Act, which includes the principles of "universality" and "accessibility", provinces are required to provide access to health services for all citizens (Canada Health Act, 1985). This presents several challenges, particularly in the case of trauma services as care must be delivered within a very limited time span. First, Canada's large landmass, coupled with its unevenly and often sparsely distributed population, makes equable service provision inherently difficult, especially in its many rural and remote communities (Schuurman et al., 2010). Physical barriers, such as mountain ranges, rivers, and lakes, which make up the Canadian landscape, also impede access. These physical barriers often combine with severe weather conditions, including snow, rain, wind, and ice, to make transporting severely injured patients to trauma centers extremely dangerous or impossible, even where air transportation programs are available. Further, the declining population of many Canadian rural communities has made the equable provision of health care services especially problematic and in some cases has led to the closure of rural hospitals (Liu et al., 2001).

As demonstrated in this paper, GIS methods are well-suited to evaluate the spatial accessibility of health services because of their unique ability to effectively describe and illustrate the spatial relationships between the characteristics of the health care system and its potential users. In addition to estimating spatial access to trauma center care (Gomez et al., 2010; Hameed et al., 2010), trauma researchers have used GIS to identify the optimum location for trauma centers, aeromedical depots, and helipads (Branas et al., 2000; Foo et al., 2010; Kivell and Mason, 1999), and determine the best mode of transport for severely injured patients (Lerner et al., 1999). Others have used GIS to identify clusters of injuries so that injury prevention programs can be targeted to the geographic locations and populations at greatest risk (Newgard et al., 2011; Warden, 2008; Warden et al., 2010; Yiannakoulias et al., 2003). Although these studies demonstrate the value of GIS as a decision support tool in health care planning, our results emphasize the importance of using accurate input data.

9. Conclusion

Despite major advances in injury prevention and control, trauma is still significant public health problem in Canada and around the world (Bell and Schuurman, 2010; World Health Organization, 2010). Because of this, many researchers have begun to investigate trauma system structures and processes as another possible means for reducing injury-related morbidity and mortality (Branas et al., 2005; Carr and Nance, 2010; Hameed et al., 2010; Kivell and Mason, 1999; Liberman et al., 2005; MacKenzie et al., 2006; Nance et al., 2009; Nathens et al., 2004a; Nathens et al., 2000; Rogers et al., 1999; Warden et al., 2010). This paper used a geospatial method to evaluate the spatial distribution of trauma center care in relation to the spatial distribution of severely injured patients. Although the future spatial distribution of major trauma may differ, our results provide a useful baseline from which to measure the continuing development of trauma systems in Canada. Results demonstrated that 68.5% of Canadian major trauma cases residing outside Quebec lived within one hour travel time of a Level I or II trauma center. This study also demonstrated how GIS can be a valuable decision support tool for health planners, but that the accuracy of results from geospatial analyzes are largely dependent upon the quality of the input data.

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