

Temporal trends in vascular trauma in Ontario, 1991–2009: a population-based study

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Abstract

Background: Vascular injuries add substantial complexity to trauma care, yet Canadian epidemiologic data on such injuries are not readily available. We conducted a retrospective cross-sectional study to examine temporal trends in the rate of hospital admissions for vascular injuries from 1991 to 2009 in Ontario.

Methods: Individuals of any age admitted to hospital because of vascular trauma in Ontario were included. Details of vascular injury and patient demographic characteristics were recorded, hospital admission rates estimated and analyses stratified by sex, age, mechanism of injury, economic status and geographic location. Time-series analysis was used to examine trends in hospital admission rates.

Results: Of the 8252 hospital admissions for vascular trauma, 4287 (52.0%) involved injuries to the upper limb and 1819 (22.0%) were due to transport-related causes. Overall, the annual rate declined significantly over time, from 3.3 per 100 000 in 1991 to 2.7 per 100 000 in 2009 ($p < 0.01$). The subgroups with the highest rates were young men, patients with a low economic status and those living in a rural location. Declines occurred in both sexes and in all age groups except those 65 years and older. The rates of vascular injury to the neck, thorax, upper limbs and lower limbs declined over time, but not the rate of abdominal vascular injury. Although the rate of non-transport-related vascular injuries declined, the rate of transport-related vascular injuries did not change significantly over time. Decreases in annual rates occurred in both low- and high-economic status groups and in urban populations but not in rural populations.

Interpretation: Overall, the annual rate of hospital admissions for vascular trauma declined significantly in Ontario over the study period. Our findings have important implications for public health and the development of injury-prevention strategies, particularly for population subgroups at high risk of vascular injury.

Injuries to the vascular system complicate trauma management and result in substantial morbidity and mortality. A study evaluating the impact of injuries on health in the Netherlands reported that one-third of injuries, including vascular injuries, required admission to hospital and about one-third were fatal.¹ The burden of injury is generally higher among men aged 25–44 years (accounting for 24%–46% of injuries in Europe), with an added risk of premature death.² This burden has a tremendous impact on the quality of life of patients, affecting their ability to work and causing pain, discomfort and substantial disability.^{3,4} Because of the life-threatening nature of vascular injuries, evaluating their temporal incidence with mortality is necessary. Assessment of vascular injury trends associated with different population characteristics can be used to identify groups at a high risk to initiate prevention strategies.

According to the Public Health Agency of Canada, injuries resulted in 13 906 deaths in 2003; moreover, the combined

economic burden associated with both intentional and unintentional injuries was estimated to be more than \$12.7 billion per year.⁵ However, data analyses on vascular injury rates in Canada

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are lacking. We conducted a population-based study to examine trends in the rate of hospital admissions for vascular injuries from 1991 to 2009 in the province of Ontario, Canada.

Methods

Study design and population

We conducted a retrospective, population-based, cross-sectional time-series study involving patients of all ages in Ontario who were admitted to hospital because of vascular injuries. We restricted the time frame to fiscal years from Apr. 1, 1991, to Mar. 31, 2010 (hereafter referred to as years 1991 to 2009). The study design was approved by the Research Ethics Board of Sunnybrook Health Sciences Centre.

Data sources

We collected data from population-based administrative claims databases of the Institute for Clinical Evaluative Sciences. Data on vascular trauma events were obtained from the Canadian Institute for Health Information Discharge Abstract Database. We used diagnostic codes from both the clinical modification of the International Classification of Diseases, 9th revision (ICD-9-CM) and the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) to identify vascular injury cases because Canadian hospitals began using ICD-10 codes in 2001. We identified transport-related injuries using the ICD-9-CM codes for external mechanism of injury and the ICD-10 codes for external cause of morbidity and mortality. Cases without these codes constituted non-transport-related injuries. The Registered Persons Database was used to identify individuals who had accessed the Ontario health care system (i.e., the contact files) — population estimates based on contact files corresponded well with actual population census estimates.

In a previous assessment of the validity of vascular injury coding using ICD-10 in the administrative databases,⁶ the positive predictive value of an ICD-10 code for vascular injury being confirmed by direct chart audit was 95%.

Outcome measures

The primary outcome measure was the annual rate of hospital admissions for vascular injuries per 100 000 population in Ontario from 1991 to 2009. Secondary outcomes included rates stratified by sex, age, anatomic site of injury, mechanism of injury, economic status and geographic location. Each vascular (arterial, venous or both) injury event was used as a unit of analysis for rate calculation. Because the number of hospital admissions and vascular injuries was almost equal, we defined a vascular event as a single hospital admission (including transfers) regardless of the number of vascular injuries per patient. The rate of vascular injury events was calculated as the annual number of vascular injury events per 100 000 population.

Patients were categorized based on their age at the time of injury (< 15, 15–24, 25–64 and ≥ 65 yr). Hospital admission rates for each subgroup were calculated and normalized by dividing the number of admissions by the age-stratified popula-

tion estimates of Ontario for the relevant period. The hospital admission rates by sex were calculated similarly, using sex-stratified population estimates. The anatomic sites assessed for vascular injury events included the neck, thorax, abdomen, upper limbs and lower limbs. Economic status was determined based on neighbourhood income quintiles (low = income quintiles 1–2; high = income quintiles 3–5). Geographic location was the place of primary residence (urban or rural); the location was determined based on the forward sortation area of Ontario, a geographic region wherein all postal codes start with the same 3 digits. The population estimates for each year were obtained from the Ontario Ministry of Health and Long-Term Care, which defined the population as the number of people accessing health services in Ontario each year.

Statistical analysis

To assess trends in rates of hospital admissions for vascular injury, we used time-series analysis using exponential smoothing models.⁷ Time-series analyses use various techniques to model autocorrelation in temporally sequenced data. In brief, the Schwarz–Bayesian criteria were used to estimate the best model fit. Stationarity was assessed using the autocorrelation function and the augmented Dickey–Fuller test. Autocorrelation, partial autocorrelation and inverse autocorrelation functions were further assessed for model parameter appropriateness and seasonality. The presence of white noise was assessed by examining autocorrelations at various lag points using the Ljung–Box χ^2 statistic. Spectral analysis was used to detect significant seasonality of hospital admissions over the study period, and data were presented using spectral density plots. White noise was detected using the Fisher kappa and Bartlett–Kolmogorov–Smirnov tests.

Rates of hospital admission for vascular injury were calculated for population subgroups stratified by sex, age, anatomic site of injury, mechanism of injury, economic status and geographic location. Differences in percentages were assessed using the χ^2 test. All *p* values were 2-sided, with a significance level of 0.05. All statistical analyses were conducted using SAS statistical software version 9.2. Descriptive statistics were used to assess the geographic variation in the distribution of hospital admission rates based on Local Health Integration Networks between Apr. 1, 2007, and Mar. 31, 2010.

Results

We identified 8252 hospital admissions for vascular trauma. Most patients were male (78.8%), aged 25–64 years (59.2%), had a high economic status (51.1%) and resided in an urban area (82.4%) (Table 1). In terms of mechanism of injury, 1819 (22.0%) were transport-related injuries. The annual rate declined significantly over the study period, from 3.3 per 100 000 in 1991 to 2.7 per 100 000 in 2009 (*p* < 0.01) (Figure 1).

Sex

The annual rate of vascular injuries decreased significantly (*p* ≤ 0.01) among males and females (Figure 2A). The annual

rate among males was about fourfold higher than that among females (5.7 v. 1.5 per 100 000). A significant variation was observed between the site of injury and patient sex ($p < 0.01$) (Appendix 1, available at www.cmajopen.ca/content/4/2/E309/suppl/DC1). More injuries to upper limbs occurred among males ($n = 3548$, 54.5%) than among females ($n = 739$, 42.3%), and more abdominal vascular injuries occurred among females ($n = 291$, 16.7%) than among males ($n = 734$, 11.3%) ($p < 0.01$).

Age

The annual rate of vascular injuries decreased significantly from 1991 to 2009 in the 3 youngest groups (Figure 2B): from 1.3 to 0.5 per 100 000 among patients aged less than 15 years ($p = 0.04$), from 5.9 to 4.7 per 100 000 among those 15–24 years ($p = 0.03$) and from 3.7 to 2.9 per 100 000 among those 25–64 years ($p < 0.01$). There was no significant change in the rate among patients 65 and older ($p = 0.8$). Although the over-

all proportion of hospital admissions was highest among patients 25–64 years old, the annual rate per 100 000 was highest among patients 15–24 years (6.6), as compared with 1.1 among patients less than 15 years, 3.8 among those 25–64 and 2.9 among those 65 and older.

Significant intergroup differences were observed in the number of hospital admissions by site of injury. The distribution of injury sites was relatively similar in the 3 younger groups except for thoracic and abdominal injuries, which were less frequent in the youngest group (Appendix 1). Patients 65 years and older differed significantly from patients in the younger groups ($p < 0.01$): they had the highest number of vascular injuries in the thorax ($n = 109$, 12.8%), abdomen ($n = 143$, 16.8%) and lower limbs ($n = 224$, 26.2%) and the lowest number of injuries in the upper limbs ($n = 290$, 34.0%).

Anatomic site of injury

Upper limbs were the most common injury site (52.0%), followed by lower limbs (16.6%), abdomen (12.4%), neck (10.0%) and thorax (9.0%) (Table 1). The annual rate per 100 000 declined significantly from 1991 to 2009 for injuries to the neck (from 0.34 to 0.26; $p = 0.03$), the thorax (from 0.32 to 0.26; $p = 0.03$), the upper limbs (from 1.7 to 1.34; $p = 0.02$) and the lower limbs (from 0.57 to 0.4; $p < 0.01$), but not for abdominal vascular injuries (from 0.36 to 0.45; $p = 0.7$) (Figure 2C). Injuries to the upper limbs were associated with the highest annual rate (1.8 per 100 000); the rate of injury at other sites was about fourfold lower (0.43 per 100 000). Appendix 1 shows the distribution of population subgroups based on the number of hospital admissions for different sites of injury.

Mechanism of injury

The annual rate of transport-related vascular injuries remained stable over the study period (0.68 to 0.62 per 100 000; $p = 1.0$), whereas the rate of injuries from other causes declined significantly from 2003 to 2009 (from 2.8 to 2.1 per 100 000; $p < 0.01$) (Figure 2D). The annual rate of non-

Table 1: Characteristics of patients admitted to hospital with vascular injuries, Ontario, 1991–2010

Characteristic	No. (%) of hospital admissions <i>n</i> = 8252
Sex	
Male	6506 (78.8)
Female	1746 (21.2)
Age group, yr	
< 15	493 (6.0)
15–24	2018 (24.5)
25–64	4888 (59.2)
≥ 65	853 (10.3)
Site of injury	
Neck	826 (10.0)
Thorax	741 (9.0)
Abdomen	1025 (12.4)
Upper limbs	4287 (52.0)
Lower limbs	1373 (16.6)
Mechanism of injury	
Transport-related cause	1819 (22.0)
Other causes	6433 (78.0)
Economic status*	
Low	3944 (47.8)
High	4220 (51.1)
Missing data	88 (1.1)
Geographic location	
Rural	1435 (17.4)
Urban	6797 (82.4)
Missing data	20 (0.2)

*Low = neighbourhood income quintiles 1–2; high = quintiles 3–5.

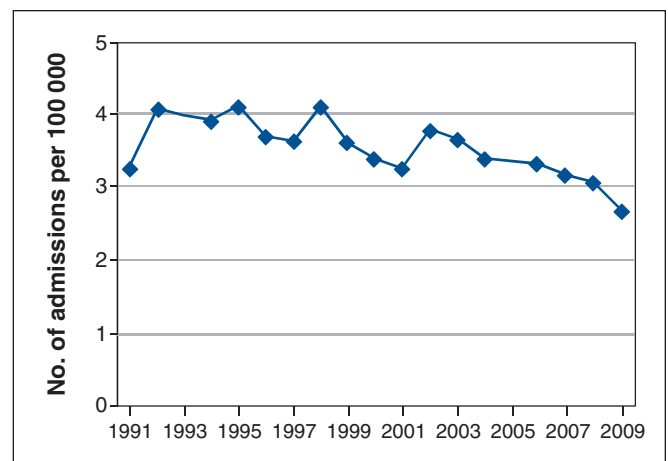


Figure 1: Annual rate of hospital admissions for vascular injuries per 100 000 in Ontario, 1991–2009.

transport-related injuries was more than threefold higher than that of transport-related injuries (2.8 v. 0.8 per 100 000). Moreover, the distribution of injury sites by mechanism of injury varied significantly ($p < 0.01$) (Appendix 1). The most common sites of transport-related injury were lower limbs ($n = 485$, 26.7%), the abdomen ($n = 464$, 25.5%) and the thorax ($n = 403$, 22.0%). For injuries from other causes, the most common site was upper limbs ($n = 4038$, 62.8%).

Economic status

The annual rate of vascular injuries declined significantly over the study period in both economic status groups (low: from 3.7 to 3.1 per 100 000; and high: from 3 to 2.4 per 100 000) ($p < 0.01$ for each) (Figure 2E). Although the overall proportion of hospital admissions was higher among patients with a high economic status (51.1% v. 47.8%), the annual rate was higher among patients with a low economic status (4.2 v. 3.1

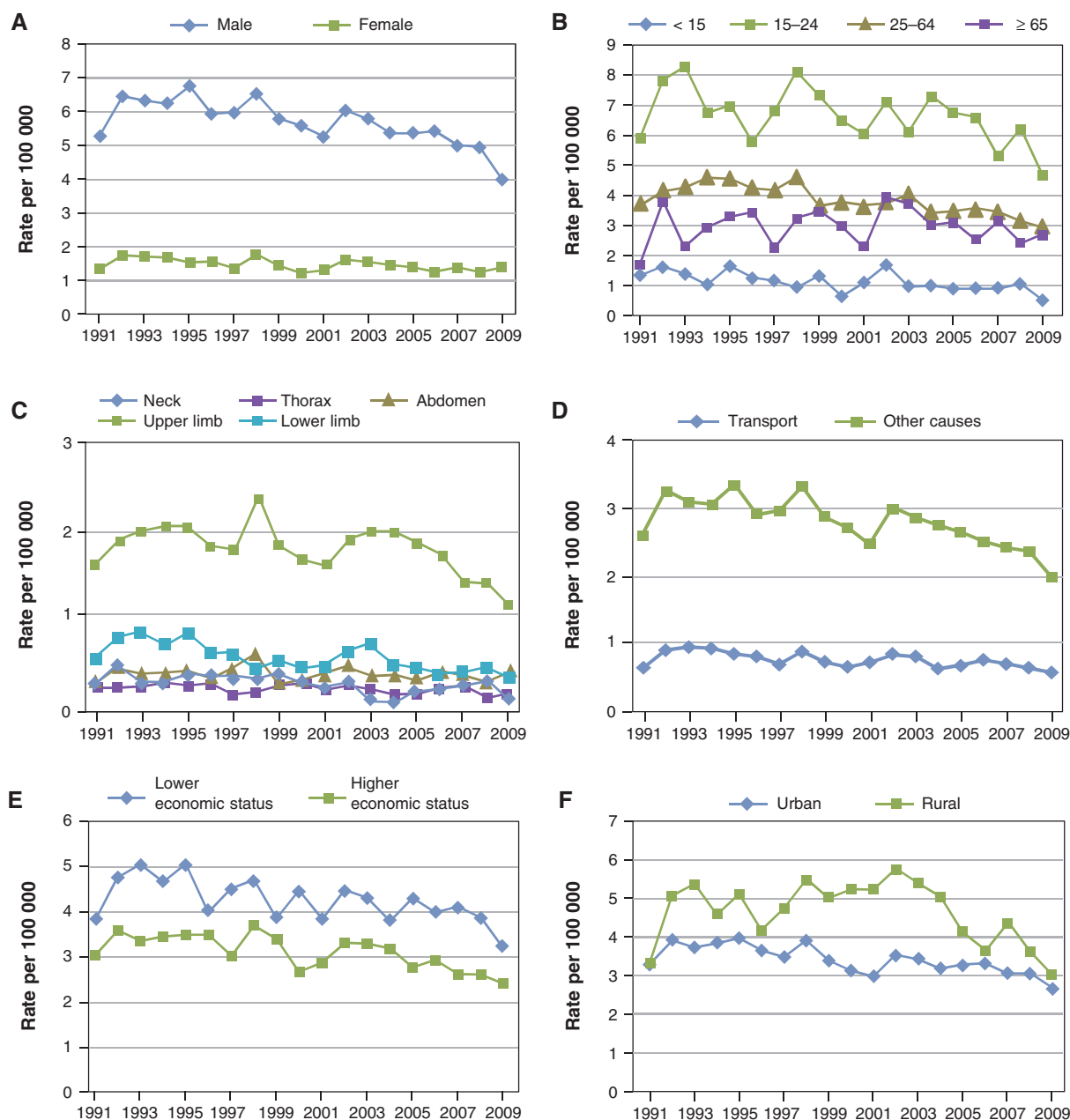


Figure 2: Annual rate of hospital admissions for vascular injuries by (A) sex, (B) age group, (C) anatomic site of injury, (D) mechanism of injury, (E) economic status and (F) geographic location.

per 100 000). No significant differences were observed in the proportion of hospital admissions by injury site between the 2 groups ($p = 0.1$) (Appendix 1).

Geographic location

Overall, the annual rate of vascular injuries decreased over time among patients in urban locations (from 3.2 to 2.6 per 100 000; $p < 0.01$); the rate remained stable in the rural population ($p = 0.6$). A nonsignificant declining trend was observed in the rural population from 2003 to 2009 (from 5.3 to 3 per 100 000) (Figure 2F). The rates by injury site differed significantly based on geographic location ($p < 0.01$; Appendix 1). Although the overall proportion of hospital admissions was higher in urban areas (82.4% v. 17.4%), the annual rate was higher in rural areas (4.6 v. 3.4 per 100 000).

Seasonal variation

When we analyzed quarterly temporal trends in the annual rates of vascular injuries, we observed significant seasonal variations in the form of annual peaks occurring during the summer months (June, July and August; $p < 0.01$) (Figure 3).

Health region

The annual rates of vascular injury by health region, based on Local Health Integration Networks, are shown in Figure 4. The highest admission rates (range 13.01–13.48 per 100 000) were observed in the North Simcoe Muskoka and the Hamilton Niagara Haldimant Brant health regions.

Interpretation

Our retrospective analysis provides an important insight into vascular injuries in Canada. We observed a decreasing temporal trend in hospital admissions for vascular injuries from 1991 to 2009. The injuries were most common among males, patients

aged 25–64 years, those with a high economic status and those residing in urban areas. In contrast, the annual rates were highest among males, patients aged 15–24 years, those with a low economic status and those residing in rural areas. The upper limb was the most common injury site, and most injuries were due to non-transport-related causes. The numbers of injuries to the abdomen and thorax were less than those involving the upper and lower limbs; however, the annual rate declined for all injury sites except the abdomen. This may have been because the nature of injury and the force necessary to cause abdominal vascular injury is primarily blunt trauma, such as motor vehicle collisions,⁸ and the annual rate of transport-related vascular injuries was relatively stable over time.

The stability observed in the rate of transport-related injuries is consistent with the high number of motor vehicle collisions and the lack of reduction in global deaths due to road-traffic crashes, most of which involve young men.^{9–14} The proportion of non-transport-related vascular injuries in our study was similar to that reported in the United States and Latin America,^{15–18} but higher than that reported in Europe, Australia and other developing countries.^{12,14} Certain factors that may contribute to a sustained high risk of transport-related injuries in Canada are the increasing number of vehicles on the road, variable road infrastructure in rural areas, reduced use of safety precautions and alcohol consumption.^{11,19,20}

We did not observe a significant decline in the incidence of vascular injuries among older and rural populations. Reportedly, rural patients with vascular injury exhibit more serious injuries and a twofold higher rate of death than such patients with nonvascular injuries; they also require longer hospital stays and higher hospital costs than their urban counterparts do.¹⁵ Our findings are concordant with those of a previous study in Canada, which reported an association between increased injury incidence and rurality, age and male sex.¹¹ Even in a developed country such as Canada, rural populations are at

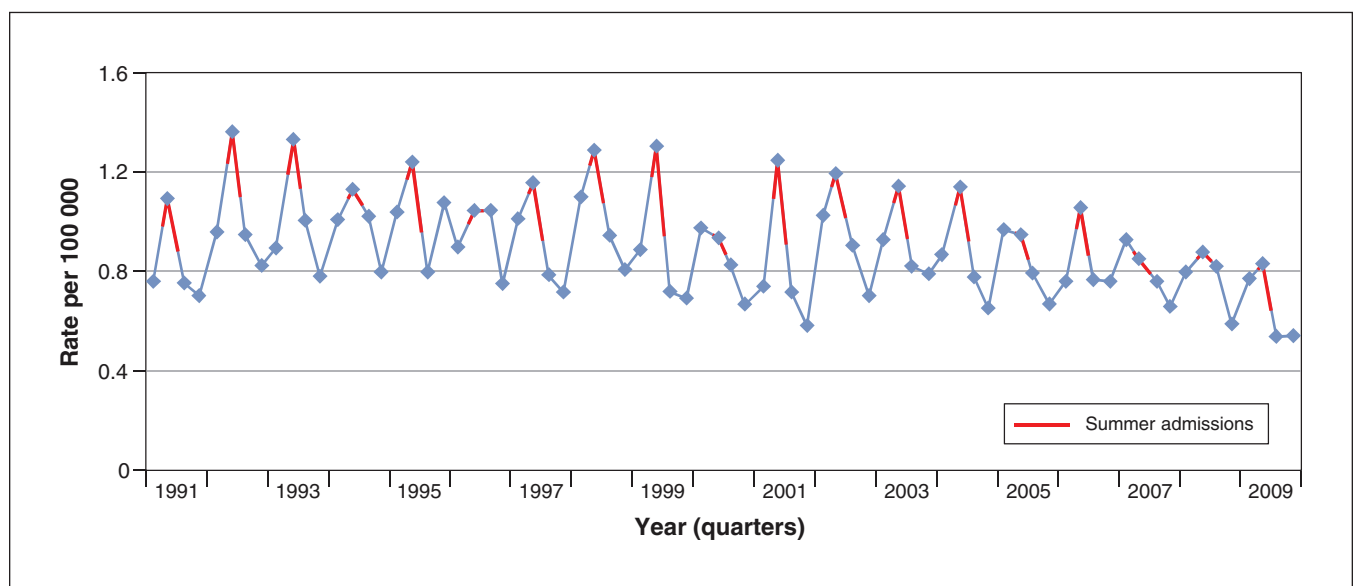


Figure 3: Seasonal variation in annual rates of hospital admissions for vascular injuries. Fisher kappa: $p < 0.01$; Bartlett–Kolmogorov–Smirnov test: $p < 0.01$.

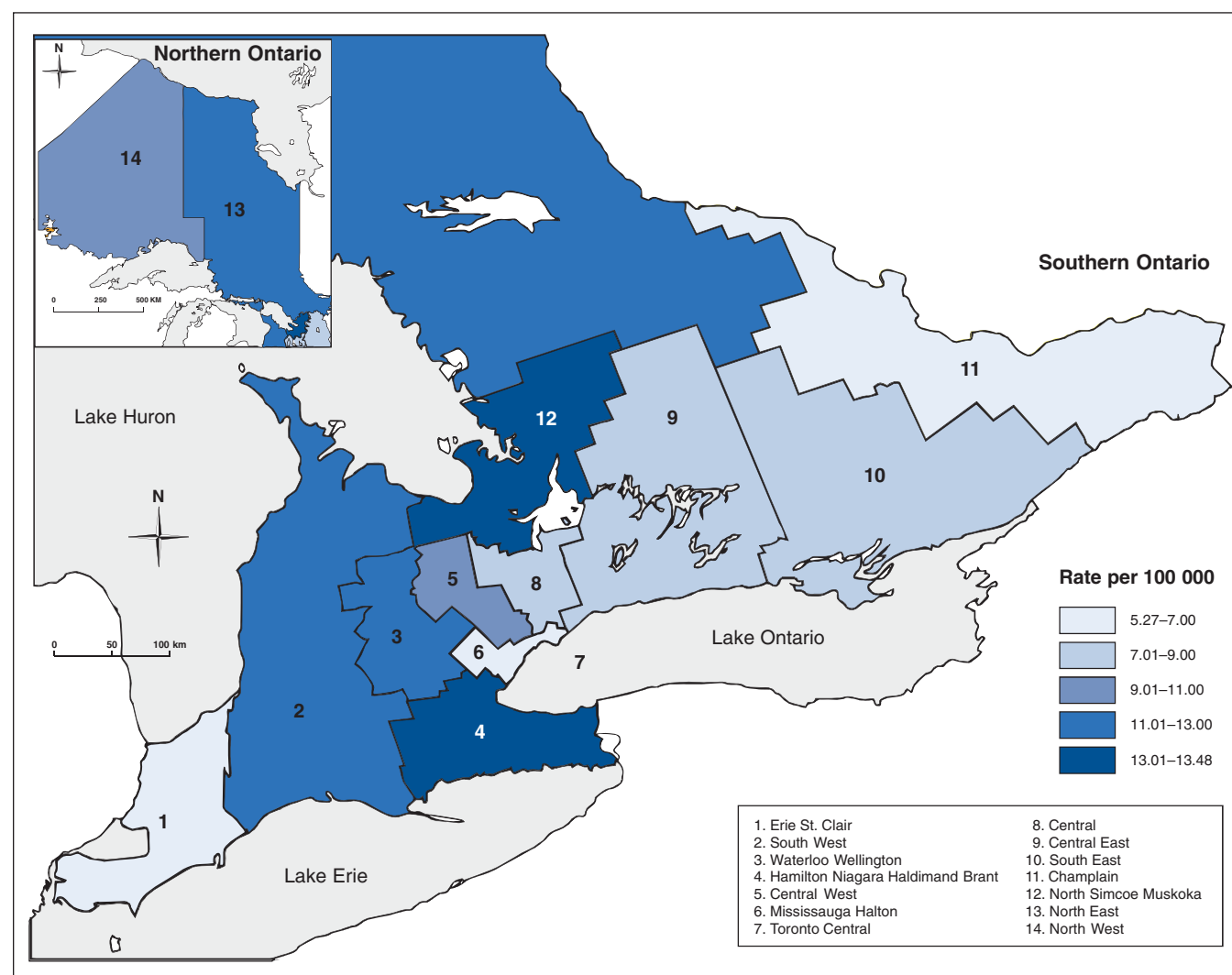


Figure 4: Geographic distribution of annual rates of hospital admissions for vascular injuries by health region in Ontario, 2007–2009.

increased risk of injuries and require improved access to emergency care and transportation facilities to prevent fatalities.^{21,22}

The incidence of vascular injuries was higher among people with a low economic status than among those with a high economic status. This finding corroborates previous reports of higher injury rates in the low-income segment of the population in Canada.^{23,24} Despite a decreasing trend in vascular injury, the sustained risk of vascular trauma in subgroups of populations must be addressed.

Analysis of quarterly based temporal trends during the study consistently identified peaks in the summer months. Summer holidays, accompanied by the absence of inclement weather, favour increased travel and transportation and encourage outdoor activities, thereby increasing the potential for vascular injuries.

Limitations

Although the coding assessed in 2 hospitals was accurately concordant with the chart reviews, it may not have reflected the

practice at all the hospitals included in the study. Undercoding or incorrect coding could cause underestimation of injury rates. Geographic location was based on the place of residence of patients rather than on the location where the injury occurred, because the latter was unavailable in the databases. The duration of hospital admission was not analyzed, and future studies could investigate the evolution of inpatient management practices over time.

The advancement and proliferation of noninvasive diagnostic imaging during the course of the study (e.g., improvements and greater availability of computed tomography angiography) may have contributed to an underestimation of the decrease of vascular injury in time. This information was not collected and should be collected in future studies.

Several factors govern the mechanism of injuries. For example, injuries due to motor vehicle collisions are known to be disproportionately higher in rural areas than in urban areas.²⁵ Given that the majority of people in Ontario reside in urban areas,²⁶ the incidence of transport-related injuries in our study

was relatively low compared with the rate of non-transport-related injuries. Yet over time, there was no decline in the incidence of transport-related injuries. Assessing the treatment protocols for transport-related injuries could be looked at in the future studies, preferably in a population that is at increased risk of motor vehicle crashes (e.g., rural).

Conclusion

Our study provides population-based evidence of a declining trend in the annual rate of hospital admissions for vascular injuries in Ontario from 1991 to 2009. The annual rate of vascular injuries was highest among young men, those with a low economic status and those residing in rural areas. The incidence of non-transport-related vascular injuries was higher than that of transport-related vascular injuries. Our findings have important implications for public health and the development of injury-prevention strategies, particularly for population subgroups at a high risk of vascular injury.

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Contributors: Mohammed Al-Omran, Muhammad Mamdani and Wayne Johnston participated in the study conception. Thomas Lindsay and Muhammad Mamdani participated in the study design and study supervision. Abdulmajeed Altoijry performed the data collection and statistical analysis. Abdulmajeed Altoijry drafted the manuscript, and all of the authors revised it critically for important intellectual content. All of the authors approved the final version to be published and agreed to act as guarantors of the work.

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