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MANUSCRIPT TITLE: Profile of trauma mortality and trauma care resources at rural emergency departments and urban trauma centres in Quebec: a population-based retrospective cohort study

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ABSTRACT

Objectives: As Canada's second-largest province, the geography of Quebec poses unique challenges for the management of trauma patients. Our objectives were to examine mortality rates among trauma patients treated at rural emergency departments (EDs) and urban trauma centres across the province of Quebec, and to compare trauma care resources and services between these settings.

Design: Retrospective cohort study.

Setting: 26 rural EDs and 33 level 1 and 2 urban trauma centres in Quebec, Canada.

Participants: 79,957 trauma cases collected from Quebec's trauma registry.

Primary and secondary outcome measures: Our primary outcome of interest was mortality (prehospital, ED, in-hospital). We also compared the availability of services and staff specialties related to trauma care are rural and urban facilities. Multivariable generalized linear mixed models were used to determine the relationship between the primary facility and mortality.

Results: Overall, 7,215 (9.0%) trauma patients were treated in a rural ED and 72,742 (91.0%) received treatment at an urban centre. Mortality rates were higher in rural EDs compared to urban trauma centres (13.3% vs. 7.9%, $p < 0.001$). After controlling for potential confounders, the odds of prehospital or ED mortality were over 3 times greater for patients treated in a rural ED (OR 3.44, 95% CI 1.88-6.28). Trauma care setting (rural vs urban) was not associated with in-hospital mortality. Nearly all of the specialized services evaluated were more present at urban trauma centres.

Conclusions: Trauma patients treated in rural EDs had a higher mortality rate and were more likely to die prehospital or in the ED compared to patients treated at an urban trauma centre.

Keywords: Rural; Urban; Trauma; Mortality; Resources.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to specifically compare trauma mortality and the availability of trauma-related resources at rural hospitals and urban trauma centres in Canada.
- This is a large retrospective cohort study of 79,957 trauma cases collected from Quebec's trauma registry over a 4-year study period.
- Our analyses included characteristics of trauma patients, their injuries, and the trauma care system to determine the independent association of these factors with mortality.
- Total prehospital times (not available in the current trauma registry) , trauma cases initially treated in remote outposts, and long-term functional outcomes were not specifically analyzed in this study.
- Our findings may not be generalizable to other jurisdictions due to differences in population, geography, resources, EMS systems, and the organizational structure of trauma care.

INTRODUCTION

Trauma is the leading cause of death for Canadians under the age of 40 and the fifth leading cause of death for Canadians of all ages.[1] Although trauma care has improved dramatically since the implementation of organized trauma systems,[2-5] evidence suggests there are considerable differences in mortality between patients receiving care in rural and urban settings.[6-10] These differences may be attributable to longer transport times and limited availability of resources and services at rural hospitals.[11] Furthermore, prehospital mortality accounts for a large proportion of rural trauma deaths.[12]

Approximately 20% of Canadians live in rural areas.[13] Rural traumas commonly occur in the workplace (e.g., industry, mining, farming), during recreational activities (i.e., "higher-risk" outdoor sports), and on the roadways (e.g., poor driving conditions, impaired driving).[6,14] These patients generally receive treatment at rural emergency departments (EDs), which often have limited access to consultation services and advanced imaging. In addition, about 60% of rural hospitals are located greater than 150 km away from a level 1 or level 2 trauma centre, far exceeding the "golden hour" of trauma care.[15-18] Moreover, access to advanced paramedic care and air medevac capabilities is limited and varies from one provincial jurisdiction to another.[19,20]

Quebec is Canada's second most populous province with 8 million inhabitants in 2016.[21] As Canada's second largest province, there are geographical challenges in providing optimal trauma care to the population. The trauma system in Quebec was launched in 1993 and involves regionalized care from rural community hospitals through to urban level 1 trauma centres. We hypothesized that rural trauma victims in Quebec have worse outcomes compared to urban trauma patients, even in a modern trauma system. The primary objective of this study was

to examine mortality rates in trauma patients seen in rural EDs and urban trauma centres across the province. As a secondary objective, we compared the availability of trauma care resources and services at rural EDs and urban trauma centres in Quebec.

METHODS

Study design and data sources

We performed a retrospective cohort study of all trauma cases in Quebec between 2009 and 2013. The protocol for this study has been previously published.[22] Data were collected from the Quebec Trauma Registry Information System (BDM-SIRTQ), a population-based registry under the Ministry of Health and Social Services. The BDM-SIRTQ contains information on victims of unintentional traumatic injuries, victims who died on arrival at the ED or during ED stay, and victims who were hospitalized in a trauma centre in Quebec. Ethical approval was obtained from the CISSS Chaudière-Appalaches Research Ethics Committee (Project MP-2016-003). This study was performed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational studies.[23]

Study definitions and inclusion criteria

For the purposes of this study, all institutions designated by the Health Authority of Quebec as level 1 or level 2 trauma centres were considered urban centres.[24] Rural EDs were defined according to the following 4 criteria: 1) located in cities with a population of less than 15,000 (2016 census data); 2) 24/7 physician coverage; 3) hospital with patient admission

capability; and 4) located more than 50 minutes of ground transport from a level 1 or 2 trauma centre. Ground transport times were estimated using Google Maps.[25]

All trauma cases occurring in Quebec during the study period and involving transport directly to a rural ED or an urban trauma centre were eligible. Regarding patient transfers, only trauma cases transferred from a rural ED to an urban trauma centre were included.

Data collection

Data were collected on patient demographics (age, sex), injury characteristics (Injury Severity Score [ISS], mechanism, type, scene of injury), mode of transport (road ambulance vs other types [e.g., air, personal vehicle]), transfer to an urban trauma centre, hospital admission, and patient mortality (prehospital, ED, or in-hospital). Data on access to 24/7 in-hospital services was obtained directly from hospitals in the context of a previous study,[26] and was updated by phone calls to participating centres in March 2017. These services included access to intensive care units (ICUs), laboratories, X-ray, computerized tomography (CT) scan, magnetic resonance imaging (MRI) and ultrasound. We also collected data on the presence of specialities commonly involved in trauma care (i.e., general and orthopedic surgery, internal medicine, neurology, anesthesiology).

Statistical analysis

Descriptive statistics were used to analyze the characteristics of trauma cases, as well as the types of services and specialities available at rural hospitals and urban centres. Means and standard deviations are presented for continuous variables, and frequencies and proportions for categorical variables. Variables with missing values are reported as such in the tables. We used

student's t-tests and chi square analysis or Fisher's exact test, as appropriate, to test for differences in characteristics between patients admitted to rural EDs and those transported directly to an urban trauma centre. To determine the relationship between the primary facility (rural ED vs. urban trauma centre) and mortality, bivariate and multivariable generalized linear mixed models were performed and adjusted for the following variables: age, sex, ISS, injury mechanism, penetrating injury, scene of injury, cranio-cerebral trauma, ambulance transport, and transfer. Mortality was considered during the prehospital setting (dead on arrival to initial ED), the ED setting (death during ED stay or during transfer from one ED to another) and the in-hospital setting (death after ED discharge to any destination [e.g., hospital department, rehabilitation]). Intraclass coefficient correlations (ICCs) were calculated to assess the percentage of variance in the model explained by the primary facility. A sensitivity analysis was performed for the subgroup of severe trauma cases (ISS ≥ 15). The same generalized linear mixed model was used to explore the yearly variation in rural versus urban mortality by adding an interaction term between primary facility and year. All analysis was performed using SAS (version 9.4, Cary, NC).

RESULTS

Fifty-nine hospitals met eligibility criteria and were included in the analysis; 26 were rural EDs and 33 were urban trauma centres (Figure 1). Of the 26 rural EDs, 18 were primary trauma centres (level 3), 6 were stabilization centres (level 4), and 2 were not designated trauma centres by the Ministry of Health and Social Services.[24]

Hospital services and staff specialists

On average, rural EDs received 490,000 patient visits per year over the course of the study. Table 1 profiles the services and staff specialists in rural EDs and urban trauma centres in Quebec. Of the 26 rural EDs, 58% (15/26) were more than 150 km from an urban trauma centre. Services available at most rural hospitals included laboratory (100%; 26/26), basic x-ray (92%; 24/26), ICUs (77%, 20/26), bedside ultrasound (73%; 19/26) and CT scanners (69%; 18/26). Few rural EDs had ultrasound services for diagnostic imaging (31%; 8/26), and none had MRI services. While the majority of rural EDs had general surgeons (73%, 19/26) and anesthesiologists (65%; 17/26) on staff, fewer than half had an internal medicine specialist (38%; 10/26), only 12% (3/26) had an orthopedic surgeon, and none had a staff neurosurgeon. In comparison, all of the services and staff specialists examined were available at every urban trauma centre.

Table 1. Characteristics of rural hospitals and urban trauma centres in Quebec, 2009-2013

Characteristic	Rural EDs N = 26	Urban TCs N = 33	p value
Distance from Level 1 or 2 trauma centre, n (%)			
>150 km	15 (58)	-	-
≤150 km	11 (42)	-	-
Types of services offered 24/7, n (%)			
Laboratory	26 (100)	33 (100)	1.00
X-ray	24 (92)	33 (100)	0.19
Intensive Care Unit	20 (77)	33 (100)	0.005
Portable ultrasound device (Bedside ED)	19 (73)	33 (100)	0.002
Computerized Tomography Scan	18 (69)	33 (100)	<0.001
Ultrasound (Radiology)[1]	8 (31)	33 (100)	0.001
Magnetic Resonance Imaging	0 (0)	33 (100)	0.001
Types of specialists, n (%)			
General surgeon	19 (73)	33 (100)	0.002
Anesthesiologist	17 (65)	33 (100)	0.002
Internal medicine specialist	10 (38)	33 (100)	0.001
Orthopedic surgeon	3 (12)	33 (100)	0.001
Neurologist	0 (0)	33 (100)	0.001

ED = emergency department; TC = trauma centre.
[1]Available on weekdays.

Profile of trauma cases

The 5-year cohort included 110,826 trauma cases in Quebec (Figure 2). Of these, a total of 30,869 cases were excluded from the analysis: 936 cases pertained to traumatic events occurring outside the province, 21,307 cases were treated at ineligible hospitals, and 8,626 cases involved patients who were transferred but not from a rural ED to an urban centre. The remaining 79,957 trauma cases were included, of which 72,742 (91.0%) were treated directly at level 1 or level 2 trauma centres and 7,215 (9.0%) were treated at rural EDs. Among patients taken to a rural ED, 3,827 (53%) were subsequently transferred to an urban centre.

Table 2 compares the characteristics of trauma cases at rural EDs and urban centres. Patients who received care at rural EDs were older than patients treated at urban trauma centres (mean age 63.3 ± 24.6 years vs. 59.1 ± 26.3 years, $p < 0.001$). There were also older than patients who were transferred from rural EDs to urban centres (mean age 63.3 ± 24.6 years vs. 50.0 ± 24.4 years, $p < 0.001$). Patients transferred from a rural facility to an urban trauma centre were more likely to be male than those who were treated at rural hospitals (61% vs. 48%, $p < 0.001$). Overall, injury severity was similar between patients seen in rural EDs (median ISS 9 (IQR 4-9)) and urban trauma centres (median ISS 9 (IQR 4 -9)). Most trauma cases were low severity (88.4% of patients had an ISS < 15). A greater proportion of patients with ISS > 25 were treated at urban centres. Falls were the most common mechanism of injury in both settings. Urban trauma centres saw a greater proportion of fall-related traumas (69% vs. 66%, $p < 0.001$), and a smaller proportion of traumas from motor vehicle collisions (15% vs. 19%, $p < 0.001$). Injuries occurred most frequently to the limbs, followed by the head and thorax. Injury types were similar between patients treated at rural EDs and urban trauma centres.

Table 2. Characteristics of trauma cases at rural hospitals and urban trauma centres

Characteristic	Rural EDs N = 3388	Transfers[1] N = 3827	p value[2]	Urban TCs N = 72742	p value[3]
Demographics[4]					
Age, mean (SD)	63.3 (24.6)	50.0 (24.4)	<0.001	59.1 (26.3)	<0.001
Male, n (%)	1624 (48)	2322 (61)	<0.001	35031 (48)	0.80
ISS, n (%)					
0-14	3052 (90)	3188 (83)	<0.001	64450 (89)	0.008
15-24	227 (7)	312 (8)	0.019	4659 (6)	0.49
25-49	91 (3)	310 (8)	<0.001	3430 (5)	<0.001
≥ 50	18 (<1)	17 (1)	0.59	203 (<1)	0.008
Injury mechanism, n (%)					
Fall	2252 (66)	2113 (55)	<0.001	50462 (69)	<0.001
MVC	628 (19)	971 (25)	<0.001	10812 (15)	<0.001
Other	508 (15)	743 (20)	<0.001	11468 (16)	0.23
Scene of injury, n (%)					
Home	1616 (47)	645 (17)	<0.001	22550 (31)	<0.001
Street/road	497 (15)	624 (16)	0.06	11908 (16)	0.009
Other	1275 (38)	2558 (67)	<0.001	38284 (53)	<0.001
Injury type,[5] n (%)					
Head	643 (19)	661 (17)		12188 (17)	
Face	321 (9)	534 (14)		9187 (13)	
Neck	37 (1)	40 (1)		977 (1)	
Thorax	709 (21)	430 (11)		10586 (15)	
Abdominal	195 (6)	198 (5)		4260 (6)	
Spinal	521 (15)	449 (12)		7906 (11)	
Upper limb	784 (23)	1182 (31)		21659 (30)	
Lower limb	1355 (40)	2069 (54)		40032 (55)	
Presence of cranio-cerebral trauma	345 (10)	437 (11)		7977 (11)	
Undetermined	176 (5)	104 (3)		2146 (3)	
Transport, n (%)					
Ambulance	2524 (74)	1749 (46)	<0.001	54745 (75)	0.32
Air	1 (<1)	5 (<1)	0.2237	61 (<1)	0.984
Other	424 (13)	252 (6)	<0.001	2757 (4)	<0.001
Unknown	439 (13)	1821 (48)	<0.001	15179 (21)	<0.001

ED = emergency department; TC = trauma centre; SD = standard deviation; ISS = Injury Severity Score; MVC = motor vehicle collision.
[1]Patients transferred from rural EDs to urban trauma centres.
[2]Significance for difference in characteristics between trauma patients admitted to rural EDs and trauma patients transferred from rural EDs to urban centres.
[3]Significance for difference in characteristics between trauma patients admitted to rural EDs and trauma patients transported directly to urban centres.
[4]Data was unavailable for 258 patients.
[5]Some patients had >1 injury type.

Trauma mortality

Overall mortality for patients seen in rural hospitals (i.e., not transferred) was 13.3% versus 7.9% for patients treated in urban level 1 and level 2 trauma centres ($p < 0.001$).

Compared to either of these groups, patients who were initially assessed and stabilized in rural EDs and subsequently transferred to an urban centre for definitive care had significantly lower overall mortality (3.1%, $p < 0.001$).

Table 3 shows crude and adjusted odds ratios for the association between mortality (prehospital or ED, in-hospital) and various patient-level and institution-level factors. The odds of death prehospital or in the ED was over 3 times greater for trauma patients treated in a rural ED (OR 3.44, 95% CI 1.88-6.28). Trauma care setting (rural vs urban) was not associated with

Table 3. Regression analysis of the relationship between rural ED admission and trauma mortality

Variable	Prehospital or ED mortality		In-hospital mortality	
	Crude OR (95% CI)	Adjusted OR[1] (95% CI)	Crude OR (95% CI)	Adjusted OR[1] (95% CI)
Admitting facility (Ref: Urban trauma centre)				
Rural ED	0.98 (0.63-1.54)	3.44 (1.88-6.28)	0.77 (0.58-1.01)	0.92 (0.75-1.13)
Age (Ref: ≥ 65)				
0-15 years	0.97 (0.74-1.26)	0.74 (0.56-0.99)	0.02 (0.01-0.04)	0.04 (0.02-0.07)
16-64 years	5.46 (4.95-6.03)	1.96 (1.74-2.21)	0.16 (0.14-0.17)	0.16 (0.14-0.18)
Male	3.65 (3.33-4.00)	1.90 (1.71-2.11)	0.90 (0.84-0.96)	1.34 (1.25-1.45)
ISS (Ref: ≥ 50)				
0-14	0.03 (0.02-0.04)	0.08 (0.06-0.11)	0.06 (0.04-0.08)	0.02 (0.01-0.03)
15-24	0.05 (0.04-0.07)	0.08 (0.05-0.11)	0.12 (0.08-0.17)	0.05 (0.03-0.07)
25-49	0.18 (0.13-0.24)	0.23 (0.16-0.33)	0.43 (0.30-0.62)	0.19 (0.13-0.28)
Injury mechanism (Ref: Other)				
Fall	0.04 (0.03-0.04)	0.04 (0.03-0.05)	2.81 (2.45-3.22)	1.17 (1.00-1.37)
MVC	0.63 (0.57-0.69)	0.45 (0.38-0.54)	1.22 (1.02-1.45)	0.84 (0.67-1.06)
Penetrating injury (Ref: Any)				
Lower/upper limbs	1.09 (0.74-1.60)	0.34 (0.23-0.51)	0.21 (0.10-0.42)	0.68 (0.33-1.38)
Thorax/abdomen/back	11.24 (9.71-13.00)	1.75 (1.46-2.09)	0.76 (0.56-1.04)	1.30 (0.91-1.86)
Scene of injury (Ref: Other)				
Road/Street	5.10 (4.60-5.66)	1.81 (1.54-2.14)	0.68 (0.60-0.77)	0.66 (0.56-0.79)
Domicile	2.86 (2.59-3.16)	4.11 (3.64-4.63)	1.82 (1.70-1.96)	1.15 (1.07-1.25)
Cranio-cerebral trauma	2.06 (1.86-2.29)	1.57 (1.38-1.79)	2.53 (2.32-2.76)	1.19 (1.06-1.33)
Ambulance transport	14.04 (10.94-18.03)	14.17 (10.89-18.43)	7.15 (6.14-8.32)	4.20 (3.59-4.91)
Transfer	0.02 (0.01-0.04)	0.01 (0.01-0.02)	0.61 (0.48-0.78)	0.97 (0.74-1.28)

ED = emergency department; OR = odds ratio; CI = confidence interval; MVC = motor vehicle collision.
[1]Adjusted for age, sex, Injury Severity Score, injury mechanism, scene of injury, penetrating injury, cranio-cerebral trauma, ambulance transport and transfer.
Intraclass coefficient: 0.15 for prehospital or ED mortality, 0.06 for in-hospital mortality.

in-hospital mortality. Similar results were obtained following a sensitivity analysis limited to severe trauma cases (ISS ≥ 15) (Supplementary Material, Table 1).

We compared adjusted mortality rate fluctuations between 2009 and 2013 for participating centres (Supplementary Material, Figure 1). Mortality in rural EDs over the five-year study period decreased by 3.74% versus 2.34% for urban trauma centres, but this difference was not significant (p = 0.18). Despite decreased trauma mortality at both urban and rural hospitals, the gap in mortality between these two settings remained constant.

DISCUSSION

This is the first study to describe and compare trauma cases presenting to rural EDs and urban centres in the province of Quebec. We found that overall mortality was greater for trauma patients seen in rural EDs (13.3% vs. 7.9%). After adjusting for potential confounders, the odds of prehospital or ED mortality were more than 3 times greater for trauma patients treated in rural EDs compared to urban trauma centres. Although mortality rates decreased at both rural and urban centres over the 5-year study period, the mortality gap between these settings remained constant. Roughly half of rural ED cases that survived the initial stabilization phase were transferred to an urban trauma centre; these patients had significantly lower mortality rates than non-transferred patients despite having greater injury severity. Compared to rural EDs, a larger proportion of urban centres offered all services (with the exception of laboratory and x-ray) and employed all types of staff specialists evaluated. Taken together, our findings demonstrate important differences in available care and outcomes for trauma patients in Quebec.

There are several limitations to this study. First, this was an analysis of data collected from a provincial trauma registry and thus subject to the inherent confines of retrospective

studies. Data for some of the variables assessed were incomplete. Additionally, the trauma registry does not capture the time interval from the 911 call to ambulance arrival at the scene which precluded our ability to calculate total prehospital times. Second, this study did not include trauma cases that were initially treated in remote outposts. Hence, our results may have minimized trauma mortality in areas that were more resource-limited, or isolated and vulnerable. Moreover, this study was not designed to compare long-term functional outcomes following trauma; this could be the focus of future studies. Finally, although this study was conducted in Canada's second-largest province, our findings may not be generalizable to other jurisdictions due to differences in population, geography, resources, EMS systems, and in the organizational structure of trauma care.

Our observation that mortality rates were higher in trauma cases at rural EDs is consistent with previous studies.[6,7,27,28] Indeed, higher mortality rates in the prehospital phase of care have been reported in the literature for more than 20 years.[7,29] In a population-based analysis of all trauma deaths in the province of Ontario, Gomez et al. found that over half of rural trauma deaths occurred in the prehospital setting.[28] Furthermore, among trauma patients that survived long enough to reach hospital, the risk of ED mortality was 3 times greater for patients injured in areas with limited access to trauma centre care. In another study of trauma patients served by emergency medical services (EMS) in rural and urban counties in Oregon and Washington, Newgard et al. found that half of rural trauma deaths occurred prehospital, and that 90% of rural deaths took place within 24 hours of injury (compared to 64% of urban deaths).[12] Although overall mortality rates did not differ between rural and urban regions, the authors suggested that the lack of a statistically significant difference may reflect a rural sample size that was underpowered to detect such a difference. It has been noted that the overall prehospital period in

the United States is almost one third longer in rural settings compared to urban environments.[30] Several studies conducted in Quebec suggest there is an association between total prehospital time and mortality in seriously injured patients, which is consistent with the concept of the "golden hour" in trauma.[31,32] Although time to definitive care is a major determinant of trauma outcomes, assessing this relationship across a field-defined population of injured persons using EMS intervals has generally produced inconclusive results.[12] Furthermore, testing the hypothesis that shorter EMS intervals improve outcomes requires rigorous study designs that are often impracticable.

This study is part of a larger project aimed at finding solutions to improve rural trauma and emergency care in Quebec.[22] A Delphi phase to this project is currently underway, as well as a large-scale qualitative study that mobilizes multiple stakeholders (citizens, decision makers, health care professionals) to participate in efforts to improve rural emergency care.[37] Potential solutions currently being explored include improving databases to better capture EMS intervals,[22] piloting the implementation of a helicopter EMS system,[33] incorporating telehealth in the prehospital and rural ED settings,[34,35] and deploying mobile trauma simulation training programs in rural EDs.[36] These solutions could be deployed in rural areas, that are most at risk for trauma mortality.

CONCLUSIONS

The results of this study illustrate significant differences in mortality and resource availability at rural hospitals and urban trauma centres in Quebec. The likelihood of mortality was over 3 times higher for patients treated at rural EDs versus urban trauma centres. While mortality rates decreased at both rural and urban facilities over the study period, the gap in

mortality between these settings remained constant; this is a finding of concern in a universal health care system. Solutions to improve trauma care in Quebec are currently being explored and deployed.

CONTRIBUTORS

RF, JP, MO, JPF, FLau and GD conceived the study, designed the protocol, and obtained research funding. RF and CTP performed the literature search. RF, FKT, and ST supervised data collection. RF, FLau and ST provided statistical advice on study design and analyzed the data. All authors contributed to interpreting the data and drafting the manuscript. All authors critically reviewed the manuscript for important intellectual content, approved the final version of the submitted manuscript, and agree to be accountable for all aspects of the work.

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COMPETING INTERESTS

None declared.

PATIENT CONSENT

Not required.

ETHICS APPROVAL

This study was approved by the CISSS Chaudière-Appalaches Research Ethics Committee (Project MP-2016-003).

DATA SHARING STATEMENT

No additional data available.

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FIGURE LEGENDS

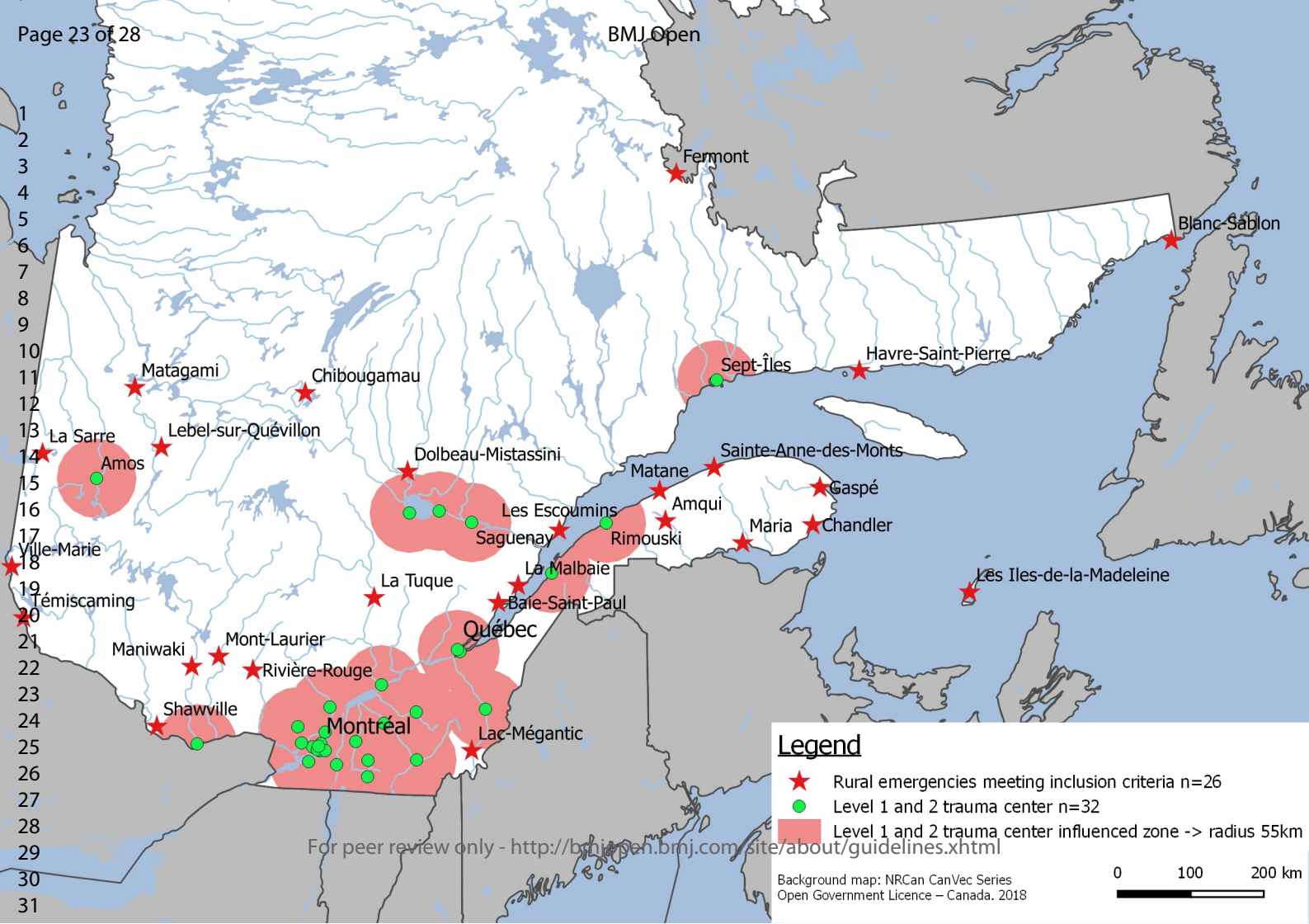
Figure 1. Map of rural emergency departments and Level 1 and 2 trauma centres included in the study

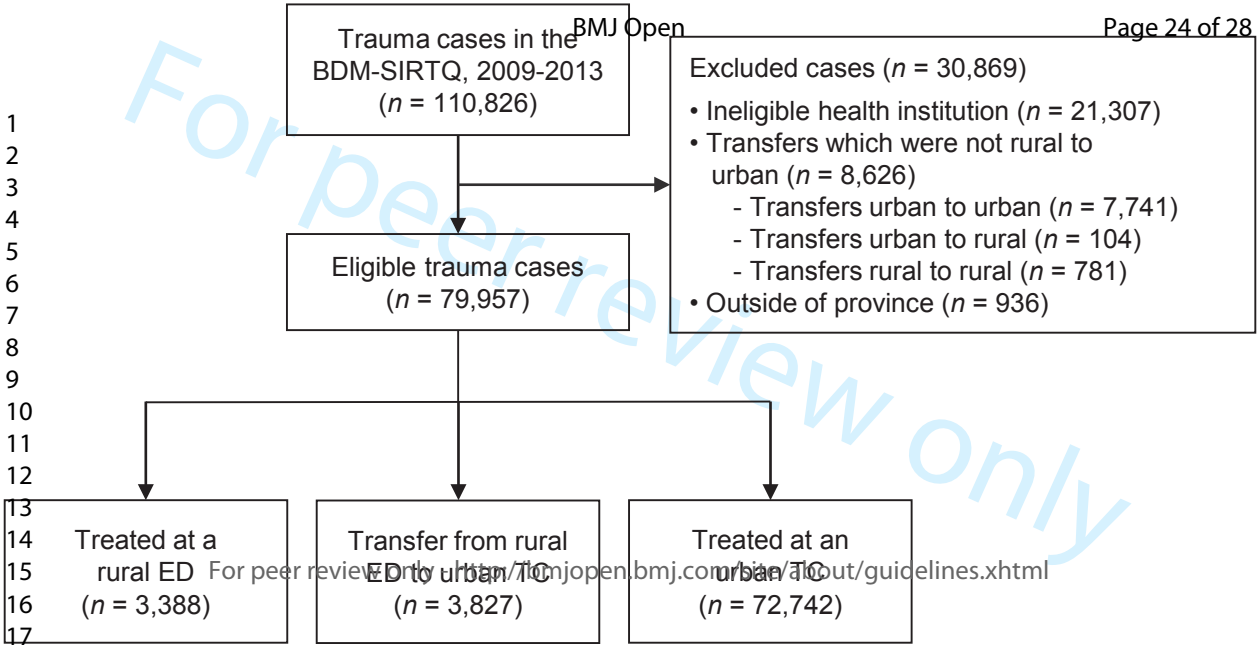
Figure 2. Flow chart of trauma cases seen in rural emergency departments and urban trauma centres in Quebec between 2009 and 2013. ED = emergency department; TC = trauma centre

SUPPLEMENTARY MATERIALS

Supplementary Table 1. Sensitivity analysis of the relationship between rural ED admission and trauma mortality

Supplementary Figure 1. Trends in trauma mortality at rural emergency departments and urban trauma centres in Quebec, 2009-2013.

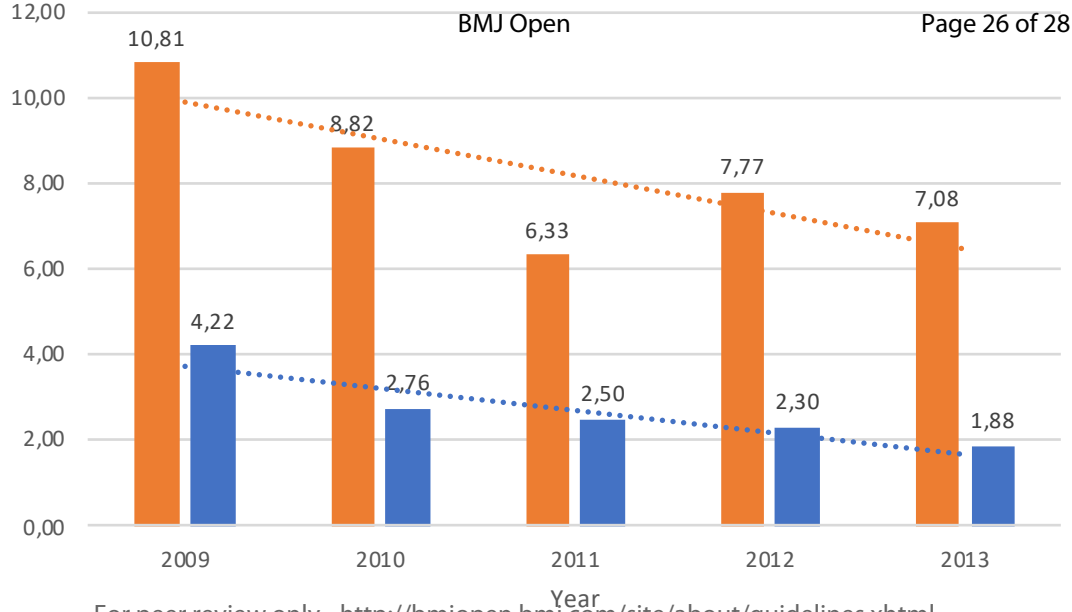




Supplementary Table 1. Sensitivity analysis of the relationship between rural ED admission and trauma mortality

Variable	Prehospital or ED mortality, Adjusted OR[1] (95% CI)	In-hospital mortality, Adjusted OR[1] (95% CI)
Admitting facility (Ref: Urban trauma centre)		
Rural ED	4.46 (2.20-9.05)	1.25 (0.81-1.93)
Age (Ref: ≥ 65)		
0-15 years	1.12 (0.61-2.08)	0.15 (0.08-0.29)
16-64 years	1.00 (0.80-1.25)	0.25 (0.21-0.29)
Male	1.15 (0.94-1.41)	0.99 (0.85-1.15)
ISS (Ref: ≥ 50)		
15-24	0.05 (0.03-0.07)	0.07 (0.05-0.10)
25-49	0.19 (0.13-0.27)	0.26 (0.18-0.39)
Injury mechanism (Ref: Other)		
Fall	0.18 (0.13-0.24)	0.92 (0.70-1.21)
MVC	0.40 (0.28-0.57)	0.64 (0.45-0.91)
Penetrating injury (Ref: Any)		
Lower/upper limbs	3.51 (1.31-9.42)	2.63 (0.69-9.98)
Thorax/abdomen/back	3.64 (2.67-4.98)	1.13 (0.70-1.82)
Scene of injury (Ref: Other)		
Road/street	1.46 (1.07-1.99)	1.04 (0.80-1.35)
Domicile	1.56 (1.22-1.99)	1.43 (1.21-1.69)
Cranio-cerebral trauma	0.96 (0.79-1.17)	1.28 (1.11-1.48)
Ambulance transport	4.14 (2.50-6.83)	4.94 (3.48-7.03)
Transfer	0.01 (0.00-0.02)	0.80 (0.49-1.33)

ED, emergency department; OR, odds ratio; CI, confidence interval; MVC, motor vehicle collision.
[1]Adjusted for age, sex, Injury Severity Score, injury mechanism, scene of injury, penetrating injury, cranio-cerebral trauma, ambulance transport and transfer.



STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **– Page 1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **– Page 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **– Page 4**
Objectives	3	State specific objectives, including any prespecified hypotheses **– Pages 4, 5**
Methods		
Study design	4	Present key elements of study design early in the paper **– Page 5**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **– Pages 5, 6**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **– Pages 5, 6**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **– n/a**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **– Pages 6, 7**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **– Pages 5, 6**
Bias	9	Describe any efforts to address potential sources of bias **– Page 7**
Study size	10	Explain how the study size was arrived at **– Page 5**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **– Pages 6, 7**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **– Pages 6, 7**
		(*b*) Describe any methods used to examine subgroups and interactions **– n/a**
		(*c*) Explain how missing data were addressed **– Page 6**
		(*d*) If applicable, explain how loss to follow-up was addressed **– n/a**
		(*e*) Describe any sensitivity analyses **– Page 7**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **– Page 8; Figure 2**
		(b) Give reasons for non-participation at each stage **– Figure 2**
		(c) Consider use of a flow diagram **– Figure 2**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **– Pages 9, 10; Table 2**
		(b) Indicate number of participants with missing data for each variable of interest **– Table 2**
		(c) Summarise follow-up time (eg, average and total amount) **– n/a**
Outcome data	15*	Report numbers of outcome events or summary measures over time **– Pages 10, 11**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included **– Pages 10, 11**
		(*b*) Report category boundaries when continuous variables were categorized **– Table 3**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **– n/a**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **– Supplemental Material, Table 1**
Discussion		
Key results	18	Summarise key results with reference to study objectives **– Page 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **– Pages 12, 13**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **– Pages 13, 14**
Generalisability	21	Discuss the generalisability (external validity) of the study results **– Page 13**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **– Page 15**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Profile of trauma mortality and trauma care resources at rural emergency departments and urban trauma centres in Quebec: a population-based retrospective cohort study

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MANUSCRIPT TITLE: Profile of trauma mortality and trauma care resources at rural emergency departments and urban trauma centres in Quebec: a population-based retrospective cohort study

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ABSTRACT

Objectives: As Canada's second-largest province, the geography of Quebec poses unique challenges for trauma management. Our primary objective was to compare mortality rates between trauma patients treated at rural emergency departments (EDs) and urban trauma centres in Quebec. As a secondary objective, we compared the availability of trauma care resources and services between these two settings.

Design: Retrospective cohort study.

Setting: 26 rural EDs and 33 level 1 and 2 urban trauma centres in Quebec, Canada.

Participants: 79,957 trauma cases collected from Quebec's trauma registry.

Primary and secondary outcome measures: Our primary outcome measure was mortality (prehospital, ED, in-hospital). Secondary outcome measures were the availability of trauma-related services and staff specialties at rural and urban facilities. Multivariable generalized linear mixed models were used to determine the relationship between the primary facility and mortality.

Results: Overall, 7,215 (9.0%) trauma patients were treated in a rural ED and 72,742 (91.0%) received treatment at an urban centre. Mortality rates were higher in rural EDs compared to urban trauma centres (13.3% vs. 7.9%, $p < 0.001$). After controlling for available potential confounders, the odds of prehospital or ED mortality were over 3 times greater for patients treated in a rural ED (OR 3.44, 95% CI 1.88-6.28). Trauma care setting (rural vs urban) was not associated with in-hospital mortality. Nearly all of the specialized services evaluated were more present at urban trauma centres.

Conclusions: Trauma patients treated in rural EDs had a higher mortality rate and were more likely to die prehospital or in the ED compared to patients treated at an urban trauma centre. Our results were limited by a lack of accurate prehospital times in the trauma registry.

Keywords: Rural; Urban; Trauma; Mortality; Resources.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to specifically compare trauma mortality and the availability of trauma-related resources at rural hospitals and urban trauma centres in Canada.
- This is a large retrospective cohort study of 79,957 trauma cases collected from Quebec's trauma registry over a 4-year study period.
- Our analyses included characteristics of trauma patients, their injuries, and the trauma care system to determine the independent association of these factors with mortality.
- Total prehospital times (not available in the current trauma registry), trauma cases initially treated in remote outposts, and long-term functional outcomes were not specifically analyzed in this study.
- Our findings may not be generalizable to other jurisdictions due to differences in population, geography, resources, EMS systems, and the organizational structure of trauma care.

INTRODUCTION

Trauma is the leading cause of death for Canadians under the age of 40 and the fifth leading cause of death for Canadians of all ages.[1] Although trauma care has improved dramatically since the implementation of organized trauma systems,[2-5] evidence suggests there are considerable differences in mortality between patients receiving care in rural and urban settings.[6-10] These differences may be attributable to longer transport times and limited availability of resources and services at rural hospitals.[11] Furthermore, prehospital mortality accounts for a large proportion of rural trauma deaths.[12]

Approximately 20% of Canadians live in rural areas.[13] Rural traumas commonly occur in the workplace (e.g., industry, mining, farming), during recreational activities (i.e., "higher-risk" outdoor sports), and on the roadways (e.g., poor driving conditions, impaired driving).[6,14] These patients generally receive treatment at rural emergency departments (EDs), which often have limited access to consultation services and advanced imaging. In addition, 44% and 54% of rural EDs are located greater than 300 km from a level 1 or level 2 trauma centre, respectively, thus far exceeding the "golden hour" of trauma care.[15-18] Moreover, access to advanced paramedic care and air medevac capabilities is limited and varies from one provincial jurisdiction to another.[19,20]

As Canada's second largest province, Quebec faces geographical challenges in providing optimal trauma care to the population. We hypothesized that rural trauma victims in Quebec have worse outcomes compared to urban trauma patients, even in a modern trauma system. The primary objective of this study was to examine mortality rates in trauma patients seen in rural EDs and urban trauma centres across the province. As a secondary objective, we compared the

availability of trauma care resources and services at rural EDs and urban trauma centres in Quebec.

METHODS

Setting

Quebec is Canada's second most populous province with 8 million inhabitants in 2016.[21] The trauma system in Quebec was launched in 1993 and involves regionalized care from rural community hospitals through to urban level 1 trauma centres. This system relies on standardized EMS resources and care providers that have the same qualifications and use the same protocols across the province. During the period this study was conducted (2009-2013), transport triage criteria were based on a combination and adaptation of the prehospital index (PHI) and high-velocity impact (HVI).[22,23] A PHI score ≥4 or the presence of any significant HVI mechanism resulted in direct transport to a trauma centre (level 1 or 2) if it was within 45 minutes of transport time from injury location. The EMS providers also followed the PHI "noncumulative 5" rule which assumes that casualties scoring a 5 (i.e., lack of vital signs) for any element of the PHI must be transported to the nearest centre (regardless of trauma designation) for initial stabilization.

Study design and data sources

We performed a retrospective cohort study of all trauma cases in Quebec between 2009 and 2013. The protocol for this study has been previously published.[24] Data were collected from the Quebec Trauma Registry Information System (BDM-SIRTQ), a population-based registry under the Ministry of Health and Social Services. The BDM-SIRTQ contains

information on victims of unintentional traumatic injuries, victims who died on arrival at the ED or during ED stay, and victims who were hospitalized in a trauma centre in Quebec. Ethical approval was obtained from the CISSS Chaudière-Appalaches Research Ethics Committee (Project MP-2016-003). This study was performed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational studies.[25]

Study definitions and inclusion criteria

For the purposes of this study, all institutions designated by the Health Authority of Quebec as level 1 or level 2 trauma centres were considered urban centres.[26] Rural EDs were defined according to the following 4 criteria: 1) located in cities with a population of less than 15,000 (2016 census data); 2) 24/7 physician coverage; 3) hospital with patient admission capability; and 4) located more than 50 minutes ("golden hour" limit with a 10-minutes margin) of ground transport from a level 1 or 2 trauma centre. Ground transport times were estimated using Google Maps.[27]

All trauma cases occurring in Quebec during the study period and involving transport directly to a rural ED or an urban trauma centre were eligible. Deaths at the scene are not included in the Quebec Trauma Registry. Regarding patient transfers, only trauma cases transferred from a rural ED to an urban trauma centre were included.

Data collection

Data were collected on patient demographics (age, sex), injury characteristics (Injury Severity Score [ISS], mechanism, type, scene of injury), mode of transport (road ambulance vs

other types [e.g., air, personal vehicle]), transfer to an urban trauma centre, hospital admission, and patient mortality (prehospital, ED, or in-hospital). Data on access to 24/7 in-hospital services was obtained directly from hospitals in the context of a previous study,[28] and was updated by phone calls to participating centres in March 2017. These services included access to intensive care units (ICUs), laboratories, X-ray, computerized tomography (CT) scan, magnetic resonance imaging (MRI) and ultrasound. We also collected data on the presence of specialities commonly involved in trauma care (i.e., general and orthopedic surgery, internal medicine, neurology, anesthesiology).

Statistical analysis

Descriptive statistics were used to analyze the characteristics of trauma cases, as well as the types of services and specialities available at rural hospitals and urban centres. Means and standard deviations are presented for continuous variables, and frequencies and proportions for categorical variables. Variables with missing values are reported as such in the tables. We used student's t-tests and chi square analysis or Fisher's exact test, as appropriate, to test for differences in characteristics between patients admitted to rural EDs and those transported directly to an urban trauma centre. To determine the relationship between the primary facility (rural ED vs. urban trauma centre) and mortality, bivariate and multivariable generalized linear mixed models were performed and adjusted for the following variables: age, sex, ISS, injury mechanism, penetrating injury, scene of injury, cranio-cerebral trauma, ambulance transport, and transfer. Mortality was considered during the prehospital setting (dead on arrival to initial ED), the ED setting (death during ED stay or during transfer from one ED to another) and the in-hospital setting (death after ED discharge to any destination [e.g., hospital department,

rehabilitation]). Intraclass coefficient correlations (ICCs) were calculated to assess the percentage of variance in the model explained by the primary facility. A sensitivity analysis was performed for the subgroup of severe trauma cases (ISS ≥ 15). The same generalized linear mixed model was used to explore the yearly variation in rural versus urban mortality by adding an interaction term between primary facility and year. All analysis was performed using SAS (version 9.4, Cary, NC).

Patient and public involvement

Neither patients nor the public were directly involved in the development of the research question, design or measures. However, a second phase of this study will employ the Delphi method to examine potential solutions for improving trauma care in Quebec; this will include participation by representatives of trauma patients. The results of both the current investigation and the second phase of this study will be disseminated to rural patients, hospitals and to the Ministry of Health.

RESULTS

Fifty-nine hospitals met eligibility criteria and were included in the analysis; 26 were rural EDs and 33 were urban trauma centres (Figure 1). Of the 26 rural EDs, 18 were primary trauma centres (level 3), 6 were stabilization centres (level 4), and 2 were not designated trauma centres by the Ministry of Health and Social Services.[24]

Hospital services and staff specialists

On average, rural EDs received 490,000 patient visits per year over the course of the study. Table 1 profiles the services and staff specialists in rural EDs and urban trauma centres in Quebec. Of the 26 rural EDs, 58% (15/26) were more than 150 km from an urban trauma centre. Services available at most rural hospitals included laboratory (100%; 26/26), basic x-ray (92%; 24/26), ICUs (77%, 20/26), bedside ultrasound (73%; 19/26) and CT scanners (69%; 18/26). Few rural EDs had ultrasound services for diagnostic imaging (31%; 8/26), and none had MRI services. While the majority of rural EDs had general surgeons (73%, 19/26) and anesthesiologists (65%; 17/26) on staff, fewer than half had an internal medicine specialist (38%; 10/26), only 12% (3/26) had an orthopedic surgeon, and none had a staff neurosurgeon. In comparison, all of the services and staff specialists examined were available at every urban trauma centre.

Table 1. Characteristics of rural hospitals and urban trauma centres in Quebec, 2009-2013

Characteristic	Rural EDs N = 26	Urban TCs N = 33	p value
Distance from Level 1 or 2 trauma centre, n (%)			
≤150 km	11 (42)	-	-
150 to 300 km	9 (35)	-	-
>300 km or no road	6 (23)	-	-
Types of services offered 24/7, n (%)			
Laboratory	26 (100)	33 (100)	1.00
X-ray	24 (92)	33 (100)	0.19
Intensive Care Unit	20 (77)	33 (100)	0.005
Portable ultrasound device (Bedside ED)	19 (73)	33 (100)	0.002
Computerized Tomography Scan	18 (69)	33 (100)	<0.001
Ultrasound (Radiology)[1]	8 (31)	33 (100)	0.001
Magnetic Resonance Imaging	0 (0)	33 (100)	0.001
Types of specialists, n (%)			
General surgeon	19 (73)	33 (100)	0.002
Anesthesiologist	17 (65)	33 (100)	0.002
Internal medicine specialist	10 (38)	33 (100)	0.001
Orthopedic surgeon	3 (12)	33 (100)	0.001
Neurologist	0 (0)	33 (100)	0.001

ED = emergency department; TC = trauma centre.
[1]Available on weekdays.

Profile of trauma cases

The 5-year cohort included 110,826 trauma cases in Quebec (Figure 2). Of these, a total of 30,869 cases were excluded from the analysis: 936 cases pertained to traumatic events occurring outside the province, 21,307 cases were treated at ineligible hospitals, and 8,626 cases involved patients who were transferred but not from a rural ED to an urban centre. The remaining 79,957 trauma cases were included, of which 72,742 (91.0%) were treated directly at level 1 or level 2 trauma centres and 7,215 (9.0%) were treated at rural EDs. Among patients taken to a rural ED, 3,827 (53%) were subsequently transferred to an urban centre.

Table 2 compares the characteristics of trauma cases at rural EDs and urban centres. Patients who received care at rural EDs were older than patients treated at urban trauma centres (mean age 63.3 ± 24.6 years vs. 59.1 ± 26.3 years, $p < 0.001$). There were also older than patients who were transferred from rural EDs to urban centres (mean age 63.3 ± 24.6 years vs. 50.0 ± 24.4 years, $p < 0.001$). Patients transferred from a rural facility to an urban trauma centre were more likely to be male than those who were treated at rural hospitals (61% vs. 48%, $p < 0.001$). Overall, injury severity was similar between patients seen in rural EDs (median ISS 9 (IQR 4-9)) and urban trauma centres (median ISS 9 (IQR 4 -9)). Most trauma cases were low severity (88.4% of patients had an ISS < 15). A greater proportion of patients with ISS > 25 were treated at urban centres. Falls were the most common mechanism of injury in both settings. Urban trauma centres saw a greater proportion of fall-related traumas (69% vs. 66%, $p < 0.001$), and a smaller proportion of traumas from motor vehicle collisions (15% vs. 19%, $p < 0.001$). Injuries occurred most frequently to the limbs, followed by the head and thorax. Injury types were similar between patients treated at rural EDs and urban trauma centres.

Table 2. Characteristics of trauma cases at rural hospitals and urban trauma centres

Characteristic	Rural EDs N = 3388	Transfers[1] N = 3827	p value[2]	Urban TCs N = 72742	p value[3]
Demographics[4]					
Age, mean (SD)	63.3 (24.6)	50.0 (24.4)	<0.001	59.1 (26.3)	<0.001
Male, n (%)	1624 (48)	2322 (61)	<0.001	35031 (48)	0.80
ISS, n(%)					
1-9	2823 (83)	2907 (76)	<0.001	56815 (78)	<0.001
10-15	229 (7)	281 (7)	0.335	7635 (11)	<0.001
16-24	227 (7)	312 (8)	0.019	4659 (6)	0.496
≥ 25	109 (3)	327 (9)	<0.001	3633 (5)	<0.001
Injury mechanism, n (%)					
Fall	2252 (66)	2113 (55)	<0.001	50462 (69)	<0.001
MVC	628 (19)	971 (25)	<0.001	10812 (15)	<0.001
Other	508 (15)	743 (20)	<0.001	11468 (16)	0.23
Scene of injury, n (%)					
Home	1616 (47)	645 (17)	<0.001	22550 (31)	<0.001
Street/road	497 (15)	624 (16)	0.06	11908 (16)	0.009
Other	1275 (38)	2558 (67)	<0.001	38284 (53)	<0.001
Injury type,[5] n (%)					
Head	643 (19)	661 (17)		12188 (17)	
Face	321 (9)	534 (14)		9187 (13)	
Neck	37 (1)	40 (1)		977 (1)	
Thorax	709 (21)	430 (11)		10586 (15)	
Abdominal	195 (6)	198 (5)		4260 (6)	
Spinal	521 (15)	449 (12)		7906 (11)	
Upper limb	784 (23)	1182 (31)		21659 (30)	
Lower limb	1355 (40)	2069 (54)		40032 (55)	
Presence of cranio-cerebral trauma	345 (10)	437 (11)		7977 (11)	
Undetermined	176 (5)	104 (3)		2146 (3)	
Transport, n (%)					
Ambulance	2524 (74)	1749 (46)	<0.001	54745 (75)	0.32
Air	1 (<1)	5 (<1)	0.2237	61 (<1)	0.984
Other	424 (13)	252 (6)	<0.001	2757 (4)	<0.001
Unknown	439 (13)	1821 (48)	<0.001	15179 (21)	<0.001

ED = emergency department; TC = trauma centre; SD = standard deviation; ISS = Injury Severity Score; MVC = motor vehicle collision.
[1]Patients transferred from rural EDs to urban trauma centres.
[2]Significance for difference in characteristics between trauma patients admitted to rural EDs and trauma patients transferred from rural EDs to urban centres.
[3]Significance for difference in characteristics between trauma patients admitted to rural EDs and trauma patients transported directly to urban centres.
[4]Data was unavailable for 258 patients.
[5]Some patients had >1 injury type.

Trauma mortality

Overall mortality for patients seen in rural hospitals (i.e., not transferred) was 13.3% versus 7.9% for patients treated in urban level 1 and level 2 trauma centres ($p < 0.001$). Compared to either of these groups, patients who were initially assessed and stabilized in rural EDs and subsequently transferred to an urban centre for definitive care had significantly lower overall mortality (3.1%, $p < 0.001$). There were 113 patients (3%) that died during the transfer interval. Table 3 shows crude and adjusted odds ratios for the association between mortality (prehospital or ED, in-hospital) and various patient-level and institution-level factors. The odds of death prehospital or in the ED was over 3 times greater for trauma patients treated in a rural ED (OR 3.37, 95% CI 1.85-6.13). Trauma care setting (rural vs urban) was not associated with in-hospital mortality. Similar results were obtained following a sensitivity analysis limited to severe trauma cases (ISS ≥ 15) (Supplementary Material, Table 1).

Table 3. Regression analysis of the relationship between rural ED admission and trauma mortality

Variable	Prehospital or ED mortality		In-hospital mortality	
	Crude OR (95% CI)	Adjusted OR[1] (95% CI)	Crude OR (95% CI)	Adjusted OR[1] (95% CI)
Admitting facility (Ref: Urban trauma centre)				
Rural ED	0.98 (0.63-1.54)	3.37 (1.85-6.13)	0.77 (0.58-1.01)	0.93 (0.76-1.14)
Age (Ref: ≥ 65)				
0-15 years	0.97 (0.74-1.26)	0.73 (0.55-0.98)	0.02 (0.01-0.04)	0.04 (0.02-0.07)
16-64 years	5.46 (4.95-6.03)	1.99 (1.76-2.25)	0.16 (0.14-0.17)	0.16 (0.15-0.18)
Male	3.65 (3.33-4.00)	1.91 (1.72-2.12)	0.90 (0.84-0.96)	1.33 (1.23-1.43)
ISS (Ref: ≥ 25)				
1-9	0.14 (0.13-0.16)	0.34 (0.29-0.39)	0.12 (0.11-0.13)	0.10 (0.09-0.11)
10-15	0.11 (0.09-0.13)	0.16 (0.13-0.19)	0.16 (0.14-0.18)	0.13 (0.11-0.15)
16-24	0.24 (0.20-0.28)	0.28 (0.23-0.34)	0.26 (0.23-0.30)	0.23 (0.20-0.27)
Injury mechanism (Ref: Other)				
Fall	0.04 (0.03-0.04)	0.04 (0.03-0.05)	2.81 (2.45-3.22)	1.16 (0.99-1.36)
MVC	0.63 (0.57-0.69)	0.49 (0.42-0.59)	1.22 (1.02-1.45)	0.86 (0.69-1.09)
Penetrating injury (Ref: None)				
Lower/upper limbs	1.09 (0.74-1.60)	0.34 (0.23-0.52)	0.21 (0.10-0.42)	0.67 (0.33-1.37)
Thorax/abdomen/back	11.24 (9.71-13.00)	1.89 (1.58-2.26)	0.76 (0.56-1.04)	1.35 (0.95-1.92)
Scene of injury (Ref: Other)				
Road/Street	5.10 (4.60-5.66)	1.87 (1.59-2.21)	0.68 (0.60-0.77)	0.66 (0.55-0.78)
Domicile	2.86 (2.59-3.16)	4.03 (3.58-4.54)	1.82 (1.70-1.96)	1.16 (1.07-1.25)
Cranio-cerebral trauma	2.06 (1.86-2.29)	1.65 (1.45-1.88)	2.53 (2.32-2.76)	1.16 (1.03-1.30)
Ambulance transport	14.04 (10.94-18.03)	14.69 (11.30-19.09)	7.15 (6.14-8.32)	4.21 (3.60-4.93)

Transfer	0.02 (0.01-0.04)	0.01 (0.01-0.02)	0.61 (0.48-0.78)	0.98 (0.74-1.29)

ED = emergency department; OR = odds ratio; CI = confidence interval; MVC = motor vehicle collision.
[1]Adjusted for age, sex, Injury Severity Score, injury mechanism, scene of injury, penetrating injury, cranio-cerebral trauma, ambulance transport and transfer.
Intraclass coefficient: 0.15 for prehospital or ED mortality, 0.06 for in-hospital mortality.

We compared adjusted mortality rate fluctuations between 2009 and 2013 for participating centres (Supplementary Material, Figure 1). Mortality in rural EDs over the five-year study period decreased by 3.74% versus 2.34% for urban trauma centres, but this difference was not significant (p = 0.18). Despite decreased trauma mortality at both urban and rural hospitals, the gap in mortality between these two settings remained constant.

DISCUSSION

This is the first study to describe and compare trauma cases presenting to rural EDs and urban centres in the province of Quebec. We found that overall mortality was greater for trauma patients seen in rural EDs (13.3% vs. 7.9%). After adjusting for potential available confounders, the odds of prehospital or ED mortality were more than 3 times greater for trauma patients treated in rural EDs compared to urban trauma centres. Although mortality rates decreased at both rural and urban centres over the 5-year study period, the mortality gap between these settings remained constant. Roughly half of rural ED cases that survived the initial stabilization phase were transferred to an urban trauma centre; these patients had significantly lower mortality rates than non-transferred patients despite having greater injury severity. Compared to rural EDs, a larger proportion of urban centres offered all services (with the exception of laboratory and x-ray) and employed all types of staff specialists evaluated. Taken together, our findings demonstrate important differences in available care and outcomes for trauma patients in Quebec.

There are several limitations to this study. First, this was an analysis of data collected from a provincial trauma registry and thus subject to the inherent confines of retrospective studies. Data for some of the variables assessed were incomplete. Furthermore, the trauma registry does not capture the time interval from the 911 call to ambulance arrival at the scene which precluded our ability to calculate total prehospital times; this is a significant limitation of this study as prehospital time is a critical potential confounder. Second, this study did not include trauma cases that were initially treated in remote outposts. Hence, our results may have minimized trauma mortality in areas that were more resource-limited, or isolated and vulnerable. Moreover, this study was not designed to compare long-term functional outcomes following trauma; this could be the focus of future studies. Finally, although this study was conducted in Canada's second-largest province, our findings may not be generalizable to other jurisdictions due to differences in population, geography, resources, EMS systems, and in the organizational structure of trauma care.

Our observation that mortality rates were higher in trauma cases at rural EDs, especially in the pre-hospital phase, is consistent with previous studies.[6,7,29,30] Indeed, higher mortality rates in the prehospital phase of care have been reported in the literature for more than 20 years.[7,31] In a population-based analysis of all trauma deaths in the province of Ontario, Gomez et al. found that over half of rural trauma deaths occurred in the prehospital setting.[30] Furthermore, among trauma patients that survived long enough to reach hospital, the risk of ED mortality was 3 times greater for patients injured in areas with limited access to trauma centre care. In another study of trauma patients served by EMS in rural and urban counties in Oregon and Washington, Newgard et al. found that half of rural trauma deaths occurred prehospital, and that 90% of rural deaths took place within 24 hours of injury (compared to 64% of urban

deaths).[12] Although overall mortality rates did not differ between rural and urban regions, the authors suggested that the lack of a statistically significant difference may reflect a rural sample size that was underpowered to detect such a difference. It has been noted that the overall prehospital period in the United States is almost one third longer in rural settings compared to urban environments.[32] Several studies conducted in Quebec suggest there is an association between total prehospital time and mortality in seriously injured patients, which is consistent with the concept of the "golden hour" in trauma.[33,34] Although time to definitive care is a major determinant of trauma outcomes, assessing this relationship across a field-defined population of injured persons using EMS intervals has generally produced inconclusive results.[12] Furthermore, testing the hypothesis that shorter EMS intervals improve outcomes requires rigorous study designs that are often impracticable.

This study is part of a larger project aimed at finding solutions to improve rural trauma and emergency care in Quebec.[24] A Delphi phase to this project is currently underway, as well as a large-scale qualitative study that mobilizes multiple stakeholders (citizens, decision makers, health care professionals) to participate in efforts to improve rural emergency care.[35] Potential solutions currently being explored include improving databases to better capture EMS intervals,[24] piloting the implementation of a helicopter EMS system,[36] incorporating telehealth in the prehospital and rural ED settings,[37,38] and deploying mobile trauma simulation training programs in rural EDs.[39] These solutions could be deployed in rural areas, that are most at risk for trauma mortality.

CONCLUSIONS

The results of this study illustrate significant differences in mortality and resource availability at rural hospitals and urban trauma centres in Quebec. The likelihood of mortality was over 3 times higher for patients treated at rural EDs versus urban trauma centres. While mortality rates decreased at both rural and urban facilities over the study period, the gap in mortality between these settings remained constant; this is a finding of concern in a universal health care system. Solutions to improve trauma care in Quebec are currently being explored and deployed.

CONTRIBUTORS

RF, JPoi, MO, JPF, FLé, FLau and GD conceived the study, designed the protocol, and obtained research funding. RF and CTP performed the literature search. RF, FKT, and ST supervised data collection. RF, FLau, JPla, JM and ST provided statistical advice on study design and analyzed the data. All authors contributed to interpreting the data and drafting the manuscript. All authors critically reviewed the manuscript for important intellectual content, approved the final version of the submitted manuscript, and agree to be accountable for all aspects of the work.

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COMPETING INTERESTS

None declared.

PATIENT CONSENT

Not required.

ETHICS APPROVAL

This study was approved by the CISSS Chaudière-Appalaches Research Ethics Committee (Project MP-2016-003).

DATA SHARING STATEMENT

Data may be obtained from the Quebec Trauma Registry Information System (BDM-SIRTQ), a population-based registry under the Ministry of Health and Social Services.
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FIGURE LEGENDS

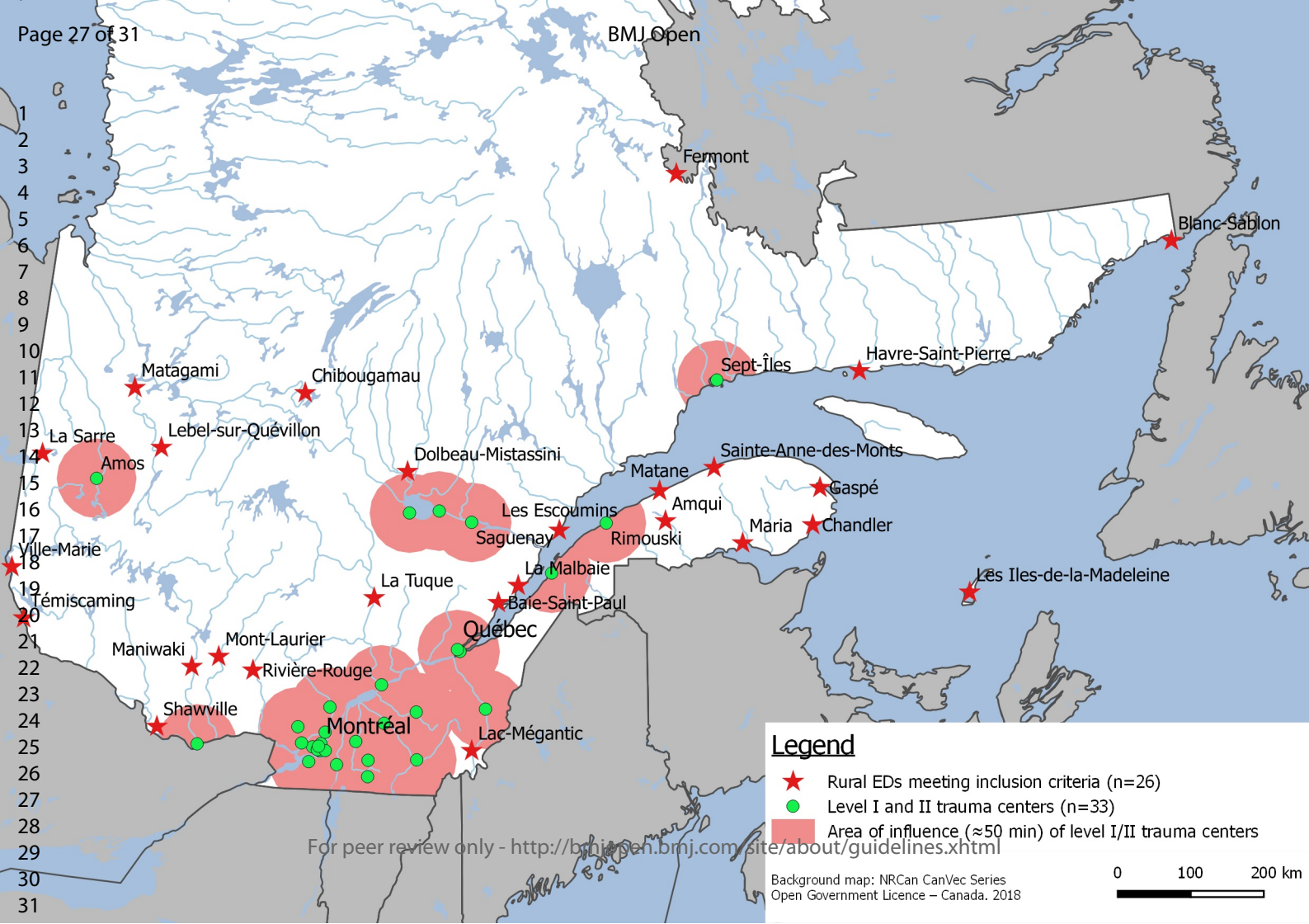
Figure 1. Map of rural emergency departments and Level 1 and 2 trauma centres included in the study

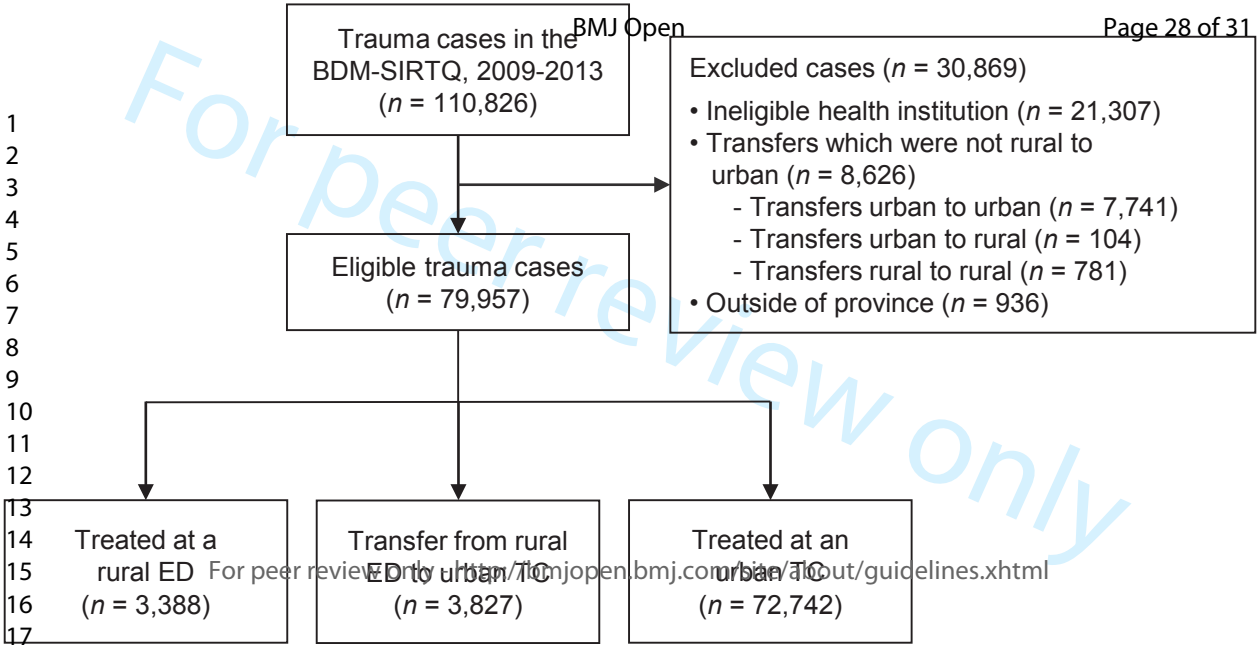
Figure 2. Flow chart of trauma cases seen in rural emergency departments and urban trauma centres in Quebec between 2009 and 2013. ED = emergency department; TC = trauma centre

SUPPLEMENTARY MATERIALS

Supplementary Table 1. Sensitivity analysis of the relationship between rural ED admission and trauma mortality

Supplementary Figure 1. Trends in trauma mortality at rural emergency departments and urban trauma centres in Quebec, 2009-2013.

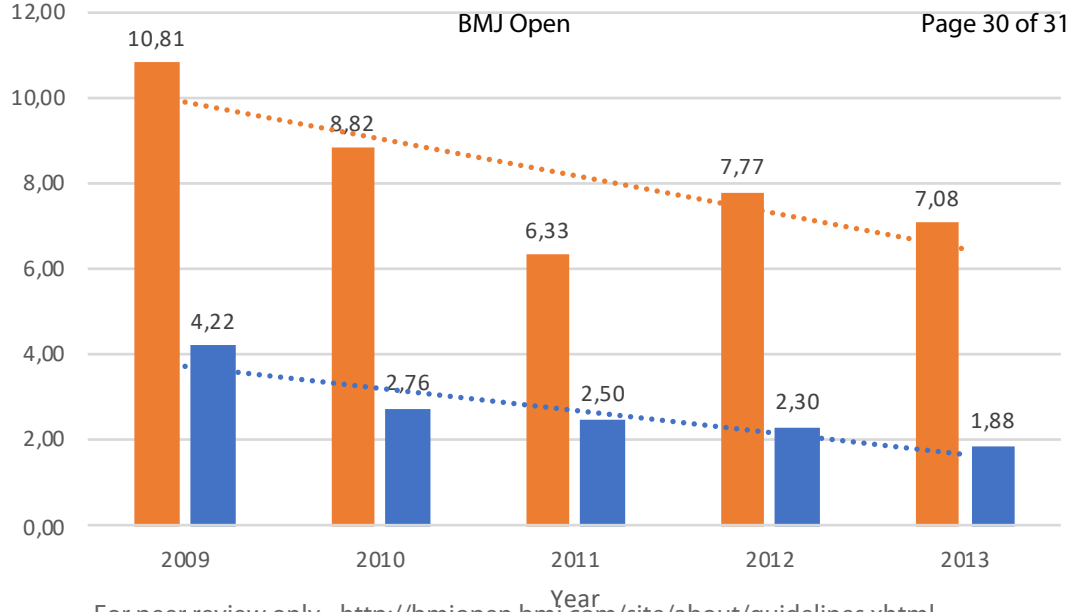




Supplementary Table 1. Sensitivity analysis of the relationship between rural ED admission and trauma mortality

Variable	Prehospital or ED mortality, Adjusted OR[1] (95% CI)	In-hospital mortality, Adjusted OR[1] (95% CI)
Admitting facility (Ref: Urban trauma centre)		
Rural ED	4.49 (2.23-9.02)	1.24 (0.80-1.92)
Age (Ref: ≥ 65)		
0-15 years	1.21 (0.66-2.20)	0.16 (0.08-0.31)
16-64 years	1.04 (0.83-1.30)	0.26 (0.22-0.31)
Male	1.15 (0.94-1.40)	0.98 (0.84-1.13)
ISS (Ref: ≥ 25)		
16-24	0.21 (0.17-0.26)	0.25 (0.21-0.29)
Injury mechanism (Ref: Other)		
Fall	0.18 (0.13-0.24)	0.91 (0.69-1.20)
MVC	0.44 (0.32-0.63)	0.68 (0.48-0.96)
Penetrating injury (Ref: None)		
Lower/upper limbs	3.51 (1.30-9.51)	2.56 (0.68-9.66)
Thorax/abdomen/back	3.84 (2.83-5.22)	1.21 (0.76-1.94)
Scene of injury (Ref: Other)		
Road/street	1.41 (1.04-1.91)	1.04 (0.80-1.34)
Domicile	1.52 (1.19-1.93)	1.44 (1.22-1.70)
Cranio-cerebral trauma	0.99 (0.82-1.19)	1.29 (1.12-1.50)
Ambulance transport	4.33 (2.63-7.13)	5.07 (3.57-7.21)
Transfer	0.01 (0.00-0.02)	0.83 (0.50-1.36)

ED, emergency department; OR, odds ratio; CI, confidence interval; MVC, motor vehicle collision.
[1]Adjusted for age, sex, Injury Severity Score, injury mechanism, scene of injury, penetrating injury, cranio-cerebral trauma, ambulance transport and transfer.



STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **– Page 1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **– Page 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **– Page 5**
Objectives	3	State specific objectives, including any prespecified hypotheses **– Pages 5, 6**
Methods		
Study design	4	Present key elements of study design early in the paper **– Page 6, 7**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **– Pages 6-8**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **– Pages 7, 8**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **– n/a**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **– Pages 7-9**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **– Pages 7-9**
Bias	9	Describe any efforts to address potential sources of bias **– Pages 7-9**
Study size	10	Explain how the study size was arrived at **– Pages 6-7**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **– Pages 8, 9**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **– Pages 8, 9**
		(*b*) Describe any methods used to examine subgroups and interactions **– n/a**
		(*c*) Explain how missing data were addressed **– Page 7**
		(*d*) If applicable, explain how loss to follow-up was addressed **– n/a**
		(*e*) Describe any sensitivity analyses **– Pages 8, 9**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **–Figure 2**
		(b) Give reasons for non-participation at each stage **– Figure 2**
		(c) Consider use of a flow diagram **– Figure 2**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **–Table 2**
		(b) Indicate number of participants with missing data for each variable of interest **– Table 2**
		(c) Summarise follow-up time (eg, average and total amount) **– n/a**
Outcome data	15*	Report numbers of outcome events or summary measures over time **– Page 14**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included – **Pages 9-14**
		(*b*) Report category boundaries when continuous variables were categorized – **Table 3**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – **n/a**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses – **Supplemental Material, Table 1**
Discussion		
Key results	18	Summarise key results with reference to study objectives – **Page 14**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – **Pages 15, 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – **Pages 15, 16**
Generalisability	21	Discuss the generalisability (external validity) of the study results – **Page 15**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based – **Page 17**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.