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ORIGINAL RESEARCH

Pre-hospital mortality among pediatric trauma patients in Nova Scotia

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Abstract

Objectives Limited data exist on pre-hospital pediatric trauma mortality in Canada. The Nova Scotia Trauma Registry is a provincial population-based registry that captures data from the Medical Examiner Service. This study examined the characteristics of pediatric trauma patient mortality in the pre-hospital and in-hospital settings.

Methods We conducted a cohort study of major pediatric traumas recorded in our provincial database from April 1, 2001 to March 31, 2018. Characteristics of pre-hospital and in-hospital deaths were compared with *t* tests and Chi-square analyses. Multivariate regression modeling was used to identify predictors of pre-hospital mortality. The geographic distribution of pre-hospital trauma was assessed using choropleth maps.

Results We identified 1,258 pediatric traumas, resulting in 217 deaths (137 pre-hospital, 80 in-hospital). Males accounted for 62.7% of fatalities. The 15–17 age group accounted for most deaths in both groups (pre-hospital 61.3%; in-hospital 41.3%). Injuries sustained in rural areas resulted in 74.7% of all deaths. For both groups, blunt trauma was the predominant injury type and motor vehicle collisions, the most prevalent injury mechanism. Patients who died pre-hospital had a higher mean age (13.3 vs. 10.7, $p=0.002$) and a greater proportion were intentional injuries (23.4% vs. 15%; $p=0.02$). Urban residency was more frequently observed in in-hospital deaths (57.5% vs. 36.5%, $p<0.001$). Pre-hospital mortality was associated with increasing age (OR 1.1), higher injury severity score (OR 1.1), and intentional injury (OR 15.6).

Conclusion Over 10% of major pediatric traumas resulted in pre-hospital death, primarily from motor vehicle collisions in rural areas. Compared to in-hospital mortality, patients who died pre-hospital were older with more severe injuries and more likely to have intentionally injured themselves. These results underscore the importance for emergency physicians and EMS systems to consider geographic factors and injury patterns, advocate for improved injury prevention programs, mental health supports, and delivery of on-scene critical care services.

Keywords Pre-hospital · Mortality · Wounds and injuries · Trauma · Pediatrics

Résumé

Objectifs Il existe peu de données sur la mortalité liée aux traumatismes pédiatriques pré-hospitaliers au Canada. La Nouvelle-Écosse. Le registre des traumatismes est un registre provincial fondé sur la population qui saisit les données du Medical

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Examiner Service. Cette étude a examiné les caractéristiques des traumatismes pédiatriques la mortalité des patients en milieu pré-hospitalier et hospitalier.

Méthodes Nous avons mené une étude de cohorte des traumatismes pédiatriques majeurs enregistrés dans notre province base de données du 1er avril 2001 au 31 mars 2018. Caractéristiques des services pré-hospitaliers et les décès hospitaliers ont été comparés aux tests-t et aux analyses du chi carré. La modélisation multivariée de régression a été utilisée pour identifier les prédicteurs de la mortalité pré-hospitalière. La répartition géographique des traumatismes pré-hospitaliers a été évaluée à l'aide de cartes choroplèthes.

Résultats Nous avons identifié 1258 traumatismes pédiatriques, entraînant 217 décès (137 pré-hospitaliers, 80 hospitalier les hommes représentaient 62,7% des décès. Le groupe des 15 à 17 ans représentait la plupart des décès dans les deux groupes (avant l'hôpital 61,3%; à l'hôpital 41,3%). Blessures subies dans les régions rurales ont entraîné 74,7% de tous les décès. Pour les deux groupes, le traumatisme contondant était le type de blessure prédominant et les collisions de véhicules à moteur, les blessures les plus fréquentes. Les patients décédés avant l'hospitalisation avaient un âge moyen plus élevé (13,3 vs 10,7, $p=0{,}002$) et une plus grande proportion étaient des blessures intentionnelles (23,4% contre 15%; $p=0{,}02$). La résidence en milieu urbain était plus fréquemment observée dans les décès à l'hôpital (57,5% contre 36,5%, $p<0.001$). La mortalité pré-hospitalière était associée à une augmentation de l'âge (CP 1.1) le score de gravité des blessures (CP 1.1) et les blessures intentionnelles (CP 15.6).

Conclusions Plus de 10% des traumatismes pédiatriques majeurs ont entraîné un décès avant l'hôpital, principalement à cause de troubles moteurs les collisions de véhicules dans les régions rurales. Comparativement à la mortalité à l'hôpital, les patients qui sont décédés avant. les établissements de soins palliatifs étaient plus âgés et plus susceptibles d'avoir intentionnellement subi des blessures plus graves. Ces résultats soulignent l'importance pour les médecins d'urgence et les systèmes de SMU pour tenir compte des facteurs géographiques et des tendances en matière de blessures, préconiser amélioration des programmes de prévention des blessures, du soutien en santé mentale et de la prestation sur place services de soins intensifs.

Mots-clés Pré-hospitalisation · Mortalité · Blessures et blessures · Traumatisme · Pédiatrie

Clinician's capsule

What is known about the topic?
Our understanding of the current landscape of pediatric trauma mortality in Canada is limited, especially in the pre-hospital setting.

What did this study ask?
Are there important differences in characteristics between pediatric major trauma patients that die pre-hospital vs. in-hospital?

What did this study find?
Pre-hospital mortality was observed in 10% of patients and was associated with increasing age, Injury Severity Score, and intentional harm.

Why does this study matter to clinicians?
Clinicians must consider how geographic/injury factors impact pre-hospital mortality and advocate for specialized EMS and rural trauma education programs.

Introduction

Despite the established social and economic burden of pediatric trauma mortality, there are few recent Canadian studies on this topic. The most up-to-date data are from a nationwide study examining unintentional injury mortality from 1950 to 2009 [1]. A major limitation of that study is the Canadian Vital Death Statistics database itself, which does not include medical examiner data. The inclusion of out-of-hospital data, in the form of death data sets, is critical to understanding the overall landscape of pediatric trauma mortality. Available Canadian data suggest a long-standing, disproportionate rate (56–85.5%) of pediatric mortality occurs in the pre-hospital setting [2–4]. Our understanding of pediatric trauma mortality is, therefore, incomplete when pre-hospital death data are not included.

Historically, most Canadian literature on pre-hospital pediatric trauma mortality was derived from the Ontario Trauma Registry, as it included death datasets. This powered researchers to examine both pre-hospital and in-hospital pediatric deaths in the context of trauma. Unfortunately, the last available death datasets date back to 2007 and there is no timeline for future releases. Since 2000, the Nova Scotia Trauma Registry has captured extensive data for all major pediatric and adult traumas, including death datasets. To our knowledge, no other provincial trauma registry has

up-to-date death dataset access, thus providing a unique opportunity to address a critical gap in the current literature.

The objectives of this study were to compare characteristics of pre-hospital and in-hospital deaths among major pediatric trauma patients and to identify predictors of pre-hospital mortality. Our overarching goals are to inform potential targeted education and prevention programs to reduce trauma-related mortality in the pediatric population and stimulate further research nationally.

Methods

Study design

This was a cohort study of all major pediatric trauma patients in Nova Scotia between April 1, 2001 and March 31, 2018. This study was performed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and was approved by the institutional research board (File #1026701).

Study setting and population

The province of Nova Scotia has a population of 983,383 [5] and is divided into 18 counties with 6 health care centers providing in-patient pediatric services (Fig. 1). The Halifax Regional Municipality is the largest urban center and is home to IWK Health Centre, the only Tertiary Pediatric Care Center and Level 1 Pediatric Trauma Center in Atlantic Canada. This hospital provides services to residents of Nova Scotia, New Brunswick, and Prince Edward Island, as well as select populations from Newfoundland and Labrador. Geographically, the island of Cape Breton comprise four counties with its largest urban center being the municipality of Sydney, which houses the only regional hospital on the island.

Eligibility criteria, data collection, and study definitions

This study included all patients under 18 years of age who sustained major trauma in Nova Scotia during the defined study period. Data were extracted from the Nova Scotia Trauma Registry, a population-based trauma registry under the Nova Scotia Department of Health and Wellness, which is collected by all tertiary and regional hospitals managed under Nova Scotia Health and the Nova Scotia Medical Examiner Service. Major trauma was defined as an Injury Severity Score (ISS) ≥ 12, penetrating injuries with an ISS ≥ 9, all Trauma Team Activations (regardless of ISS), and all trauma-related deaths in the pre-hospital setting or within 24 h of ED arrival. Mortality was categorized as pre-hospital (i.e., deaths occurring on-scene or during transport) or in-hospital (including ED deaths). We defined traumatic brain injury as a maximum Abbreviated Injury Scale (AIS) score of 3 or greater and categorized AIS scores as previously described [6]. Any patients who sustained a traumatic

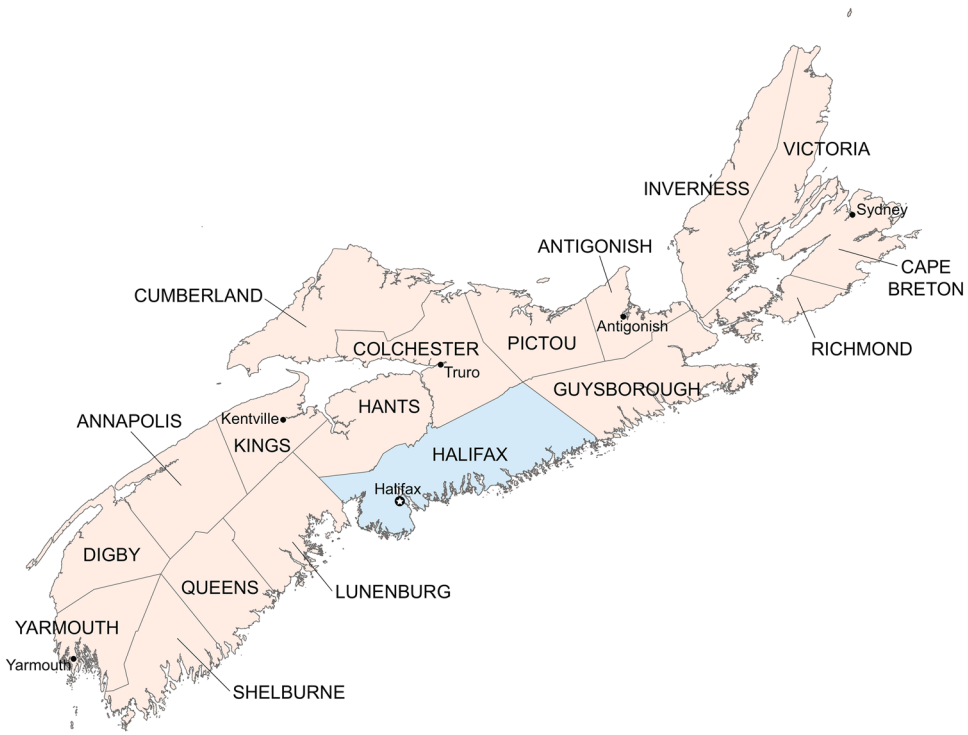

Fig. 1 Map of Nova Scotia and its 18 counties (capitalized), capital city (starred), and municipalities with health centers that include pediatric in-patient services in rural (orange) and urban (blue) regions of the province

injury outside of the province and were transported to Nova Scotia facilities for definitive management were excluded.

Data analysis

Descriptive statistics were used to characterize pediatric trauma mortality, which was categorized as pre-hospital (i.e., deaths occurring on scene or during transport) or in-hospital (including ED deaths). To compare patient characteristics, we used *t* tests and Chi-square analysis, as appropriate. A multivariate logistic regression model was created to assess for variables associated with pre-hospital mortality while controlling for covariates including age, sex, injury severity, location of injury, and mechanism of injury. A p value < 0.05 was considered statistically significant. To visualize geographic variation in injury and mortality rates, choropleth maps were created using ArcGIS Pro Version 29. All analyses were performed using IBM SPSS Statistics Premium, Version 29. To maintain privacy, any cell sizes smaller than 5 are reported as "$n < 5$".

Results

This study identified 1258 major pediatric traumas, where 17.2% of injuries were fatal. Of the 217 deaths, 63.1% occurred in the pre-hospital setting and 72.3% of these were due to injuries sustained in rural areas. Table 1 compares characteristics of patients that died pre-hospital vs. those that died in-hospital. Any cases with missing values were included in the analysis and are reported in Table 1. Males accounted for 62.7% of all deaths; sex was similar between both groups. The 15- to 17-year age group accounted for most deaths (pre-hospital 61.3%; in-hospital 41.3%), representing 53.9% of all deaths. Compared to in-hospital mortality, patients who died pre-hospital were older (13.3 ± 4.9 years vs. 10.7 ± 6.3 years, $p = 0.002$) and a larger proportion of these deaths were due to intentional injuries (23.4% vs. 15.0%; $p = 0.016$). Rural residents accounted for a larger proportion of pre-hospital deaths (40.1% vs. 36.5%, $p < 0.001$), and motor vehicle collisions were the primary cause of injury in both groups. Traumatic brain injuries were observed in 48.8% of pre-hospital deaths and 62.4% of in-hospital deaths.

Results of the regression modeling for predictors of pre-hospital mortality are shown in Table 2. After adjusting for potential confounders, pre-hospital mortality was associated with increasing age (OR 1.08, 95% CI 1.0–1.1), increasing ISS (OR 1.08, 95% CI 1.02–1.1) and intentional injury (OR 15.6, 95% CI 5.5–44.5). Compared to burns/drownings/asphyxias, the odds of pre-hospital mortality were lower in patients with blunt trauma (OR 0.2, 95% CI 0.07–0.4) and penetrating trauma (OR 0.2, 95% CI 0.07–0.8). Rural location of injury was not associated with pre-hospital death in the regression model.

Choropleth maps were generated to analyze the geographic distribution of annualized injury rates (Fig. 2A), overall mortality rates (Fig. 2B), and pre-hospital mortality rates (Fig. 2C) across the province. Halifax County has the largest pediatric population [7] and showed annualized rates of injury, overall mortality, and pre-hospital mortality of 42.5, 4.2, and 3.0 per 100,000 person per year, respectively. The highest rates of major pediatric trauma injuries and mortality were observed among patients who were injured in Victoria County (82.8 per 100,000 py; 39 per 100,000 py) and Richmond County (55.9 per 100,000 py; 18.6 per 100,000 py). Victoria County (30.5 per 100,000 py) and Inverness County (10.2 per 100,000 py) had the highest rates of pre-hospital mortality in the province.

Discussion

Interpretation of findings

The current study found that one in six major pediatric traumas were fatal, with nearly two-thirds of all deaths occurring in the pre-hospital setting. Compared to in-hospital deaths, patients that died pre-hospital were older and more likely to have been involved in a motor vehicle collisions. Intentional injuries were also observed more frequently among pre-hospital deaths. Traumatic brain injuries were common in both pre-hospital and in-hospital deaths. After controlling for potential confounders, pre-hospital mortality was still associated with increasing age, greater injury severity, and intentional injury. The in-hospital group had significantly more urban residents and higher rates of Trauma Team Activations, which is thought to be attributed to the proximity of patients to tertiary level emergency care. This theory aligns with the data presented using choropleth maps, where despite moderate to high rates of traumatic injuries across the province, lower mortality rates were observed in the county housing our Level 1 Trauma Center. We identified concerning disparities in trauma outcomes in the incidence rates of injury and mortality in Cape Breton, a remote geographical region in Nova Scotia. This could be attributed to longer EMS access times, as well as greater distance to regional and tertiary hospitals. Collectively, these findings imply that there are two distinct populations of pediatric trauma in Nova Scotia with measurable and unique patient, trauma and geographic characteristics affecting patient outcomes.

Table 1 Comparison of the characteristics of 1,258 pediatric major trauma patients by location of death

Characteristics	Overall ($n=1258$)	Pre-hospital deaths ($n=137$)	In-hospital deaths ($n=80$)	p value[a]
Age, %				**0.02**
15–17 years	46.4	61.3	41.3	
10–14 years	23.7	19.7	22.5	
5–9 years	11.3	8.8	10.0	
1–4 years	12.8	7.3	20.0	
< 1 year	5.8	n < 5	6.3	
Age, mean ± SD	11.6 ± 5.7	13.3 ± 4.9	10.7 ± 6.3	**< 0.001**
Male sex, %	65.1	65.0	58.8	0.4
Residence, %				**< 0.001**
Urban	60.7	36.5	57.5	
Rural	35.5	40.1	40.0	
Missing	3.8	23.4	2.5	
Trauma Team Activation, %	52.7	n < 5	37.5	**< 0.001**
Injury Severity Score[b], mean ± SD	18.9 ± 14.9	35.8 ± 24.6	31.0 ± 17.9	0.1
Glasgow Coma Scale (scene)[c], mean ± SD	12.6 ± 4.0	3.2 ± 0.4	4.2 ± 3.1	0.5
Max Abbreviated Injury Scale head score[d], %				0.2
5–6	11.8	25.5	43.7	
4	18.2	17.5	11.2	
3	6.1	5.8	7.5	
1–2	16.1	5.8	6.2	
Location of injury, %				0.2
Urban	24.9	27.7	20.0	
Rural	74.7	72.3	78.7	
Missing	4.1	0	n < 5	
Place of injury, %				0.6
Street/highway	52.1	52.6	45.0	
Home	20.7	35.0	40.0	
Sport/athletic area	5.2	0	0	
Other or unspecified	22.0	12.4	15.0	
Intent of injury, %				**0.02**
Unintentional	94.1	76.6	78.8	
Intentional	4.2	23.4	15.0	
Unknown	1.7	0	6.3	
Injury type, %				0.2
Blunt	86.2	57.7	70.0	
Penetrating	6.6	9.5	2.5	
Drowning/asphyxia	3.7	21.2	20.0	
Burn	3.4	10.9	7.5	
Unknown	$n<5$	$n<5$	0	
Primary cause of injury, %				**0.001**
Motor vehicle collision	35.6	46.0	27.5	
Fall	13.4	0	n < 5	
Off-road vehicles[e]	9.8	3.6	12.5	
Pedestrian	9.8	5.8	11.3	
Cyclist	5.8	$n<5$	$n<5$	
Self-harm	3.9	23.4	15.0	
Fire/explosion/burn	3.3	10.9	6.3	
Firearm	1.4	$n<5$	$n<5$	
Drowning	0.7	$n<5$	$n<5$	

Table 1 (continued)

Characteristics	Overall ($n=1258$)	Pre-hospital deaths ($n=137$)	In-hospital deaths ($n=80$)	p value[a]
Suffocation/strangulation/hanging	$n<5$	$n<5$	$n<5$	
Other	16.0	3.6	12.5	

[a]p values for comparison of pre-hospital deaths vs. in-hospital deaths

[b]Data missing for 241 patients

[c]Data missing for 422 patients

[d]Data missing for 602 patients

[e]Includes all-terrain vehicles, dirtbikes, and snowmobiles

Table 2 Logistic regression model of association between pre-hospital mortality and patient variables

Variable	Odds ratio	95% CI	p value
Age[a]	1.1	1.02–1.1	**0.006**
Male sex	0.8	0.4–1.3	0.3
Rural location of injury	1.2	0.7–2.03	0.6
Injury Severity Score	1.1	1.06–1.1	**< 0.001**
Injury type[b]			
Blunt trauma	0.2	0.07–0.4	**< 0.001**
Penetrating trauma	0.2	0.07–0.8	**0.02**
Intentional injury	15.6	5.5–44.3	**< 0.001**

C-statistic = 0.87 (indicating a strong model)

[a]Per year increase in age

[b]Reference is patients with burns/drownings/asphyxias

Comparison to prior studies

The characteristics of overall trauma mortality in our study are congruent with pre-existing Canadian [1] and Nova Scotian [8] literature, including predominant mechanisms and causes of injury. Although there is little literature comparing pre-hospital and in-hospital pediatric mortality on a national or provincial level, the characteristics we observed among pre-hospital trauma deaths were similar to those reported in a Manitoba autopsy database study [3] and an Ontario report of chief coroner data [2]. However, our investigation did find a lower rate of pre-hospital mortality (10.6% vs. 56–85% [2–4]). With regard to geographical distribution, a recent study on traumatic brain injury in Nova Scotian adults found similar disproportionate injury rates in Cape Breton and determined that disparities in social economic status contributed to the observed differences in injury rates [9]. Most pre-hospital deaths in our study resulted from motor vehicle collisions, as has been reported in other studies [4, 5]. From 2009 to 2014, all pediatric traumatic injuries in Canada were reviewed and evidence-based Injury Prevention Priority Scores across three prevention perspectives (mortality, injury severity and resource utilization) were developed, which determined that falls, if prevented, would provide the most benefit to the largest proportion of the Canadian pediatric population [10].While falls were the second most common mechanism of injury among pediatric trauma patients in Nova Scotia in the current study, there were no pre-hospital deaths and very few in-hospital deaths in these patients.

A recent study from the United States demonstrated that using principal component analysis as a dimensionality

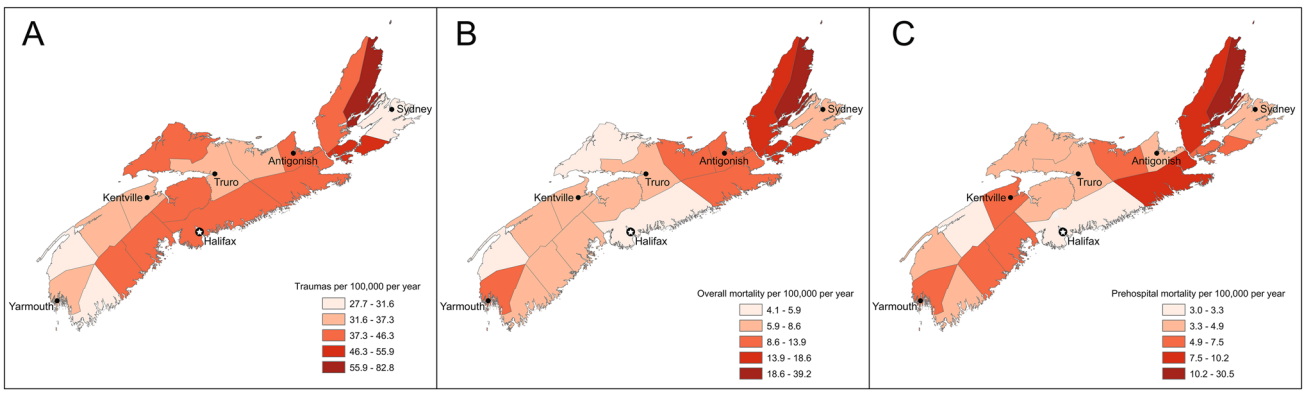

Fig. 2 Choropleth map of the geographical distribution of overall rate of traumatic injury (**A**), overall mortality (**B**), and pre-hospital mortality per 100,000 population per year, by county in Nova Scotia

reduction and feature extraction technique to identify potential multivariate predictors performs better for predicting pediatric trauma outcomes compared to using individual variables [11]. Head-to-head comparison of the literature is challenging due to the limited number of papers and established impact of geographical trends, as well as a high degree of variability in methodology and research questions across studies. There is also variation in policies and practices regarding termination of resuscitation in the pre-hospital setting. In Nova Scotia, Emergency Health Services (EHS) paramedics are trained in Basic Life Support or Advanced Life Support and provide emergency response via ground ambulance with critical care support from EHS LifeFlight helicopter, fixed-wing aircraft and ground transport. Current EHS guidelines recommend the paramedic crew to consider not starting resuscitative efforts in patients with traumatic cardiac arrest prior to EMS arrival, signs of prolonged death, asystole on arrival with no cardiopulmonary resuscitation for 10 min prior to EMS arrival, or a valid directive indicating no resuscitation [12].

Strengths and limitations

Our study addresses a major gap in Canadian pediatric trauma literature. The Nova Scotia Trauma Registry is unique in Canada in its inclusion of medical examiner data. This enabled us to compare pediatric deaths in the pre-hospital setting with patients that died in-hospital. However, this data has several limitations. First, it is a provincial study, which impacts its external validity due to the variability in trauma injury and mortality patterns across provinces. Furthermore, the definition of trauma varies between studies, especially in terms of classification (generalized, minor vs. major), ISS cut-offs (range of 12 to 15), and age of inclusion (< 16 vs. < 18 years). This study specifically focused on injured children who fit the criteria for major trauma consistent in current Canadian literature, which may explain why our pre-hospital mortality rates were lower than previously published studies. Larger studies, ideally with data sourced from a national trauma registry, would shed more light on geographical differences in pediatric trauma mortality across provinces. Although data were obtained from a robust population-based trauma registry which captures data from the Nova Scotia Medical Examiner Service and has quality-control procedures for accurate data entry, some variables were missing values. It is also important to consider that the analysis period ended prior to the COVID pandemic, where an increase in trauma-related presentations to pediatric emergency departments was observed across the country [13]. This warrants ongoing surveillance to capture pediatric trauma-related mortality on a national level.

Clinical implications

We have demonstrated that both pre-hospital and in-hospital pediatric trauma mortality are influenced by geography. The landscape of pediatric trauma is highly dynamic across our large nation, yet there is limited up-to-date literature available to inform clinical practice and injury prevention initiatives. These results underscore the importance for emergency physicians and EMS systems to consider geographic factors and injury patterns, advocate for improved injury prevention programs, mental health supports, and delivery of on-scene critical care services. The integrated use of medical examiner data into trauma programs would greatly improve further research on factors influencing pre-hospital mortality. On an education and systems level, emergency physicians and EMS specialists must advocate locally and nationally for rapid and skilled scene responses, standardization of pediatric pre-hospital trauma care, and the enhancement of rural trauma education and practice.

Research implications

This current study identifies several important research considerations. Given that the incidence of pediatric trauma-related mortality is significant, especially in the pre-hospital setting, it is critical for future provincial and national studies to include medical examiner data to accurately capture a distinct population of trauma patients. Furthermore, choropleth mapping of injuries and mortality highlighted several critical differences in patient outcomes from urban and rural areas. This study adds to the pre-existing literature that highlights proximity and access to tertiary care in Canada impact patient outcomes [14].

Conclusion

In the present study, we observed that one in ten major pediatric traumas resulted in pre-hospital death, which primarily occurred in rural areas and were caused by motor vehicle collisions. Compared to pediatric trauma patients who died in-hospital, those who died in the pre-hospital setting were older, had more severe injuries, and were more likely to have intentionally injured themselves. There were also notable geographical disparities between injury and mortality rates. These findings help elucidate the current landscape of pediatric trauma-related mortality in Nova Scotia. Given the lack of nationwide literature on this topic, these results should stimulate further research in what drives these pre-hospital factors and how geographical disparities and mechanisms of injury influence pediatric trauma-related mortality. A broader understanding on both regional and national levels about critical features of pediatric mortality will inform

targeted injury prevention programs, mental health supports, and delivery of on-scene critical care services.

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Author contributions This study was conceived and designed by R.K., A.S., M.E., R.G., and J.E. Data analysis was performed by M.E. and N.K. All authors contributed to interpretation of the results. The manuscript was drafted by R.K. All authors were involved in critically reviewing the manuscript, provided final approval of the version submitted for publication, and have agreed to be accountable for all aspects of the work presented in the manuscript.

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Availability of data and material Study data are not available.

Code availability Not applicable.

Declarations

Conflict of interest None declared.

Ethics approval Ethics approval was obtained from the Nova Scotia Health Research Ethics Board (File #1026701).

Consent to participate Waiver of consent was granted by the Nova Scotia Health Research Ethics Board.

Consent for publication Waiver of consent was granted by the Nova Scotia Health Research Ethics Board.

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