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Clinical paper

Epidemiology of paediatric out-of-hospital cardiac arrest in Ontario, Canada

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Abstract

Background: There are no Canadian epidemiological studies of Paediatric Out-of-Hospital Cardiac Arrest (POHCA) for ≥20 years. Understanding the epidemiology of POHCA is key to prevention, education, and management strategies.

Methods: We applied a validated algorithm to hospital administrative databases to describe paediatric (age 1 day to ≤18 years) atraumatic OHCA in Ontario from 2004–2020.

Results: The cohort included 1,839 paediatric patients with atraumatic POHCA occurring at a median (IQR) age of 2 (0–12) years with 721 (39.2%) POHCA events in <1-year-olds. Males accounted for 71.1% (n = 1123) of the cohort. Crude incidence of children with POHCA who were transported to an Emergency Department was 4.2/100,000 with an increase annually over the study period (p = 0.0065). Thirty percent (n = 560) lived in a neighbourhood with the lowest income quintile, while 13.6% (n = 251) lived in a neighbourhood with the highest income quintile, 78.6% (n = 1444) presented to a non-academic hospital, and the majority (n = 1533, 83.4%) did not have significant comorbidities. Survival to hospital discharge was achieved in 167 (9.1%). Less than 6 (<3.6%) patients had a repeat POHCA in the year following the index event.

Conclusions: This is the largest Canadian POHCA cohort and the first to describe its incidence, comorbidities, and sociodemographic characteristics. We found an increase in annual crude incidence, POHCA mostly occurred in healthy children, and survival was similar to other cohorts. There were more than double the number of POHCA events in children living in the lowest income quintile neighborhoods compared to the highest. Most children presented to non-academic hospitals first.

Keywords: Paediatric out-of-hospital cardiac arrest, Epidemiology, Sociodemographic factors, Outcomes

Introduction

Paediatric Out-of-Hospital Cardiac Arrest (POHCA) is rare and has a survival rate of less than 10%.[1,2] Most survivors suffer new significant neurologic impairment.[2,3] However, as there are very few epidemiologic studies of POHCA, the incidence and outcomes of POHCA in most jurisdictions is unknown. In the United States (U.S.), the annual incidence of POHCA is between 5 and 10/100,000 children.[1,2] The incidence has not significantly changed in the years 2007–12.[1] There are no Canadian epidemiological studies of POHCA for at least 20 years.[4]

Large POHCA registries typically use Utstein criteria to describe cardiac arrest characteristics.[5] Utstein criteria are valuable for benchmarking systems of care, for describing trends, and studying cardiac arrest processes. The Utstein demographic criteria are limited to patient characteristics at the time of the POHCA, i.e., age, sex, and level of independence (which is more applicable to adult cardiac arrest victims). Consequently, we know very little about a POHCA patient's past medical history. Understanding who is at risk of a POHCA is key to prevention and education strategies. We also know very little about sociodemographic characteristics of POHCA patients, and nothing has been reported in Canada on this topic. In

Abbreviations: CCI, Canadian Classification of Health Interventions codes, CPR, cardiopulmonary resuscitation, ED, Emergency Department, ICD-10-CA, International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada, OHCA, Out-of-hospital cardiac arrest, PCMI, Paediatric Comorbidity Index, PCP, Primary Care Paramedic, POHCA, Paediatric out-of-hospital cardiac arrest

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https://doi.org/10.1016/j.resplu.2023.100442
Received 1 May 2023; Received in revised form 18 July 2023; Accepted 24 July 2023

the U.S., a recent study reported racial and neighborhood-level socioeconomic disparities in bystander CPR provision and POHCA outcomes, specifically among Black and Hispanic children.[6] Further disparities have been found in the prevalence of automated external defibrillator training among Latino populations and in those with lower educational attainment in the U.S.[7] The risk of rural dwelling has not been examined. This area of inquiry is particularly important for health care access planning.

Our primary study aim was to describe the epidemiology of POHCA in Ontario, Canada's most populous province, from 2004 to 2020. More specifically, we aimed to describe the cohort by pre-existing comorbidities, sociodemographic features, and outcomes.

Methods

We conducted a retrospective cohort study of all patients who had a POHCA event and were transported to an Emergency Department (ED) from April 1, 2004 to March 31, 2020 in Ontario, Canada. Ontario's population is approximately 14.5 million, with 2.7 million children. We used the following databases: National Ambulatory Care Reporting System (emergency department visits), Discharge Abstract Database (hospital admissions), Registered Persons Database (vital statistics), Ontario Inter-Censal Population Estimates and Projections, Canadian Organ Replacement Registry, and Ontario Cancer Registry. These datasets were linked using unique encoded identifiers and analyzed at ICES. ICES is an independent, non-profit research institute which collects and analyzes health care and demographic data for health system evaluation and improvement. We identified the POHCA population by using a validated algorithm which used International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA) codes for cardiac arrest, Sudden Infant Death Syndrome, drowning, and asphyxiation combined with Canadian Classification of Health Interventions (CCI) codes for cardiopulmonary resuscitation (CPR) (Appendix 1).[8] We included all patients 1 day to <18 years who presented to an ED by ground ambulance with an index cardiac arrest. We applied data cleaning exclusions to exclude those who had a missing or invalid health card number, age, or sex, had a death date before the index cardiac arrest, or were not an Ontario resident. We also excluded those with concurrent trauma codes within the same ED visit (Appendix 2).

We calculated crude incidence using population estimates as the denominator for children for each year of study (Ontario Ministry of Health and Long-Term Care, IntelliHealth Ontario). We calculated a 5-year moving average for each year between fiscal years 2006/2007 and 2017/2018 by taking the mean of the incidence rates of the past 2 years, current year, and next 2 years. We used Poisson regression to test for significance for the annual incidence rate. We described age, sex, year of index event, income quintile (neighborhood level), rural or urban location of 1st ED, and type of hospital ('small' has <100 beds and/or is a mental health hospital, 'community' has >100 beds, and 'academic' includes Children's Hospitals) at presentation. Determination of rurality was done by applying the postal code of the index ED to the postal code conversion file, where the definition of rural is a community where the population is <10,000. For comorbidities, we used a 2-year look-back period to identify patients who had a hospitalization or ED visit with a diagnosis of cancer, cerebral palsy, tracheostomy, chronic respiratory/liver/cardiac/or renal failure, congenital cardiac malformation or arrhythmia, transplant, or mental health disorder (Appendix 3). We also calculated the Pediatric Comorbidity Index (PCMI) for each patient.[9] The PCMI was validated in about 1 million children in the U.S. to predict the 1-year risk of hospitalization using 24 common conditions.[9] In contrast to our listed comorbidities reflecting diagnoses from hospitalization and ED, the PCMI includes outpatient healthcare encounters and drug prescriptions.

For outcomes, we reported (1) survival to ED discharge (includes patients who were subsequently admitted to hospital), (2) survival to hospital discharge (includes patients who survived to ED discharge and were not admitted to hospital), and (3) the risk of repeat POHCA in the year following the index event. We performed bivariate analyses for baseline characteristics and survival to hospital discharge, our primary outcome. The use of the data in this project is authorized under section 45 of Ontario's Personal Health Information Protection Act (PHIPA) and does not require review by a Research Ethics Board.

Results

The final cohort included 1,839 unique paediatric patients with atraumatic POHCA event during 2004–2020 in Ontario. One hundred and forty patients had been excluded for having concurrent trauma codes. Median (IQR) age was 2 (0–12) years with 721 (39.2%) less than 1 year at the time of the index POHCA event (Table 1). Males accounted for 1123 (71.1%) of the cohort. Nine hundred and twenty-eight (50.5%) children had ICD-10 codes for undifferentiated cardiac arrest, 586 (31.9%) for SIDS, 203 (11%) for asphyxiation, and 122 (6.6%) for drowning. Crude incidence over the study period was 4.2/100,000. Five year moving average was between 3.8 and 4.8/100,000 (Fig. 1) with a significant upward trend in annual incidence (p = 0.0065). Thirty percent (n = 560) of the cohort lived in a neighborhood in the lowest income quintile, while 13.6% (n = 251) lived in a neighborhood with the highest income quintile. Seventy five percent of the cohort presented to an ED in an urban setting. Seventy nine percent (n = 1444) of the cohort first presented to a non-academic, non-Children's hospital following the index POHCA event.

The majority (n = 1,533, 83.4%) of patients did not have a history of hospitalization or ED visit for significant comorbidities. The most common comorbidity was congenital cardiac malformation for 147 (8.0%) of patients. The majority (n = 66.7%, 1226) had a PCMI of 0, while 256 (13.9%) had a PCMI of $\geq$10.

Four hundred and eighteen (22.7%) children survived to be admitted to hospital or were discharged alive from ED, and 167 (9.1%) survived to hospital discharge (including those who were discharged alive from ED). Thirty-one children (1.7%) were discharged home from the ED. Of those in their respective age groups, only 29 (4%) children less than 1 year of age survived to hospital discharge, while children aged 1–11 years had a survival of 11.8% (n = 72) and 12–17 years had a survival of 13.0% (n = 66). Less than 6 (<3.6%) patients had a repeat POHCA in the year following the index event. The median (IQR) hospital length of stay following the POHCA was 3 (1–9) days. Survival to hospital discharge was associated with age (p < 0.001), index event year (p < 0.001), and presentation to an academic or Children's Hospital (p = 0.02). There was a trend toward presentation to an urban ED (p = 0.05). Comorbidities and neighborhood income quintile were not associated with survival to hospital discharge, although there was a trend to lower survival for lower income quintiles.

Table 1 – Patient Characteristics and Bivariate Analyses for Survival to Hospital Discharge.

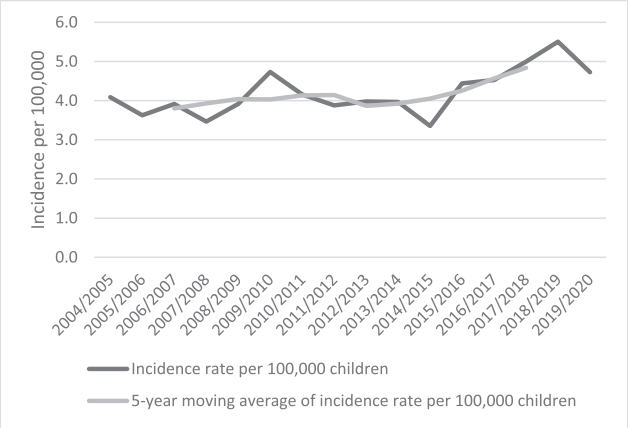
	Total (*N* = 1839)	Survived to Hospital Discharge (*N* = 167)	Did not Survive to Hospital Discharge (*N* = 1672)	*P*-value
Age				
Mean (SD)	5.49 ± 6.40	7.92 ± 6.35	5.25 ± 6.36	<0.001
Median (IQR)	2 (0–12)	7 (1–14)	1 (0–12)	<0.001
<1 year	721 (39.2%)	29 (4.0%)	692 (96.0%)	<0.001
1–11 years	611 (33.2%)	72 (11.8%)	539 (88.2%)	
12–17 years	507 (27.6%)	66 (13.0%)	441 (87.0%)	
Female, *N* (%)	716 (38.9%)	73 (10.2%)	643 (89.8%)	0.184
Index year, *N* (%)				
2004/2005–2010/2011	772 (42.0%)	48 (6.2%)	724 (93.8%)	<0.001
2011/2012–2015/2016	530 (28.8%)	65 (12.3%)	465 (87.7%)	
2016/2017–2019/2020	537 (29.2%)	54 (10.1%)	483 (89.9%)	
Income quintile, *N* (%)				
Quintile 1	560 (30.5%)	44 (7.9%)	516 (92.1%)	0.248
Quintile 2	377 (20.5%)	30 (8.0%)	347 (92.0%)	
Quintile 3	345 (18.8%)	33 (8.9%)	338 (91.1%)	
Quintile 4	280 (15.2%)	29 (10.4%)	251 (89.6%)	
Quintile 5	251 (13.6%)	31 (12.4%)	220 (87.6%)	
Missing	26 (1.4%)			
Rural or urban location of ED, *N* (%)				
Rural	157 (8.5%)	6 (3.8%)	151 (96.2%)	0.051
Urban	1,380 (75.0%)	130 (9.4%)	1,250 (90.6%)	
Missing	302 (16.4%)	31 (10.3%)	271 (89.7%)	
Type of Hospital, *N* (%)				
Small	119 (6.5%)	9 (7.6%)	110 (92.4%)	0.02
Community	1,325 (72.1%)	108 (8.2%)	1,217 (91.8%)	
Academic or Children's Hospital	395 (21.5%)	50 (12.7%)	345 (87.3%)	
Comorbidities in the previous 2 years, *N* (%)*				
Cancer	16 (0.9%)			
Cerebral palsy	56 (3.0%)			
Tracheostomy	19 (1.0%)			
Chronic respiratory, liver, or renal failure	8 (0.4%)			
Congenital cardiac malformation	147 (8.0%)			
Heart failure	31 (1.7%)			
Transplant	6 (0.3%)			
Cardiac arrhythmia	87 (4.7%)			
Hospital admission for mental health	54 (2.9%)			
None of the comorbidities listed above	1,533 (83.4%)	132 (8.6%)	1,401 (91.4%)	0.116
PCMI Index ≥10, N (%)	256 (13.9%)	23 (9.0%)	233 (91.0%)	0.954

* Individual comorbidities not included in bivariate analyses for survival to hospital discharge.

Discussion

This is the largest Canadian paediatric atraumatic out-of-hospital cardiac arrest (POHCA) cohort, and the first to describe incidence, comorbidities, and sociodemographic characteristics for this population. This is also the first study to use a validated algorithm to create a POHCA cohort using large hospital administrative databases. Our study found: (1) a relatively low incidence of POHCA in Ontario, with a gradual increase in annual incidence over the 17-year study period, (2) POHCA occurred mostly in previously healthy children, and (3) survival was associated with presentation to an academic or Children's Hospital.

The crude incidence of atraumatic POHCA in Ontario from 2004 to 2020 was 4.2/100,000. Based on the 87.3% sensitivity of the validated algorithm, the estimated incidence of POHCA in Ontario was 4.8/100,000 (or *n* = 2,107). The algorithm's known limitation is not being able to capture children with POHCA who were not transported to a hospital. All children who receive resuscitative efforts by EMS are transported. The EMS policies for resuscitating and transporting these children have not changed over the study period. Our corrected incidence is similar to Victoria, Australia (4.9/100,000, period: 2000–2016),[10] higher than The Netherlands (3.5/100,000, period: 2015–17),[11] and lower than a North American cohort (8.3/100,00, period: 2007–12).[1] The Dutch study included traumatic POHCA and may have missed some cases and the North American study included patients who did not receive resuscitation efforts by Emergency Medical Services (EMS) and reflected 11 subregions of North America, including 2 urban Southern Ontario regions. Our study



Trend for annual rate: p=0.0065

Fig. 1 – Incidence and 5-year Moving Average. Trend for annual incidence: p = 0.0065.

includes all regions in Ontario. It is important to consider inclusion criteria and data limitations when comparing incidence rates.

The absolute number of POHCA events in each of the past 5 years is higher than any previous year since 2004. There is also an increased incidence rate over the study period (p = 0.0065), reflected in the per-year incidence (Fig. 1). This rise in incidence has not been previously described and, in fact, the studies from Australia and North America showed no trends in incidence between 2000 and 2016, and 2007 and 2012, respectively.[1,10] There is no obvious explanation for our observation as the identification of specific risk factors for POHCA was beyond the scope of this study. However, our study reflects a more recent and longer study period. One can hypothesize, however, that perhaps there have been significant preventive (e.g., public health, health care access) measures that have been scaled back, or more prevalent risk factors, e.g. more prevalent comorbidities. It is also possible that more children received resuscitative efforts by EMS and were thus included in this study. Future studies will explore these ideas.

The rural population of Ontario accounts for 13.3% of the population, yet only 8.5% of this cohort presented to a rural ED. This may reflect reality or this may be due to unbalanced missingness (accounting for 16.4% of this variable), a smaller paediatric rural population, or some rural POHCA patients not transported to an emergency department. The POHCA study from The Netherlands showed a higher incidence of POHCA in urban regions compared to non-urban regions.[11]

The more compelling sociodemographic finding was the unbalanced neighborhood income quintile for the POHCA cohort. There were more than double the number of POHCA events in children living in the lowest income quintile neighbourhoods compared to the highest income quintile neighbourhoods. This income-based disparity in incidence has not been previously described, although ethnic-based disparities in incidence of POHCA has been described in New Zealand and Israel.[12,13] Sociodemographic disparities in outcomes of the POHCA in the U.S. have been documented.[6,14] The result from our study may reflect a disparity in access to preventative healthcare and education. Further studies will explore this possibility.

Interestingly, only about 16% of the cohort had a previous hospitalization or ED visit for a significant comorbidity. This is an important finding that reinforces the idea that CPR is a lifesaving skill that should be learned by everyone, not just those who are in regular contact with people with significant medical conditions. Not surprisingly, the most prevalent comorbidities were cardiac in nature, including congenital cardiac malformation, arrhythmias, and heart failure, and accounted for more than all of the other comorbidities combined. This population is a good place to start for targeted discharge education for families and caregivers, and early access to defibrillation. We also described the cohort by their Pediatric Comorbidity Index (PCMI). A score of $\geq$10 has about 25% annual risk of hospitalization and a score of $\leq$5 has a < 5% risk of hospitalization. Fourteen percent had a PCMI $\geq$10, 80% had a PCMI of $\leq$5, and approximately 67% of the POHCA cohort had a PCMI of 0, which reinforces that most POHCA events occur in mostly healthy children.

Survival to hospital discharge of 9.2% was similar to recent reports from the U.S. (10%), but lower than Japan (1-month survival of 17%).[6,15] Recently, in Japan, the government has provided subsidies for the EMS system and paediatric critical care service enhancements.[15] In our study, survival was associated with older age. This is consistent with existing literature, where POHCA in infancy is more often associated with other negative predictors such as increased frequency of unwitnessed arrest and more sinister initial rhythm (asystole).[6] Interestingly, events that occurred in fiscal years 2011/12–2015/16 had improved survival. It is unclear why this has occurred. The study period is pre-COVID-19 pandemic during which there were no major changes in public health. The Heart and Stroke Foundation of Canada (the resuscitation council of Canada) issued resuscitation guidelines in 2010 and 2015, but the recent changes were not controversial and were more likely to contribute to better outcomes. They included a focus on high-quality CPR, feedback devices, and post-cardiac arrest care. It will be important to monitor the POHCA population's survival outcomes, which can be easily done by periodically applying the POHCA algorithm to health administrative databases in a surveillance program.

Children who presented to a Children's or academic Hospital's ED had improved survival. This is not unexpected as there are many factors that may explain this result. First, in the rural or remote prehospital setting in Ontario, POHCA events are attended to by Primary Care Paramedics (PCP) with a limited scope of practice. For example, a PCP cannot administer epinephrine for POHCA, a life saving medication in POHCA. The EMS transport times to the patient and to a hospital are often greater for rural emergencies. In addition, the EDs of smaller hospitals may not be resourced (equipment and personnel) to manage all paediatric emergencies.[16] This study reinforces the importance of supporting our community partner paramedic services and hospitals with the resources to provide the initial care for critically ill children.

This study has limitations. The method of applying a validated algorithm to identify a population is limited by imperfect sensitivity and specificity. The algorithm we used had relatively strong validation statistics.[8] Furthermore, all patient encounters were included (except for children not transported by EMS to hospital), whereas registries rely on voluntary data input. We did not have access to arrest characteristics but that was not within the scope of this study. Ultimately, linking POHCA registry data with health administrative data will provide the most comprehensive analysis of this population. Finally, we observed an interesting trend in survival with respect to neighbourhood income quintile, which will be further explored in a future study. Future investigation will also look at longer term outcomes, such as 6 and 12-month survival.

Conclusion

This is the largest Canadian POHCA cohort and the first to describe incidence, comorbidities, and sociodemographic characteristics for this population. This is the first study to use a validated algorithm to create a POHCA cohort using large hospital administrative databases. We found a significant increase in annual crude incidence over the 17 year study period, POHCA mostly occurred in healthy children, and survival was similar to other reported cohorts. There were more than double the number of POHCA events in children living in the lowest income quintile neighbourhoods compared to the highest income quintile neighbourhoods. Most children with POHCA presented to non-academic, non-Children's hospitals first. This study presents opportunities for further research in sociodemographic disparities for POHCA and for advocating for more support for rural paramedics and community hospitals who are the first responders for children with POHCA.

CRediT authorship contribution statement

Janice A. Tijssen: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Marisha McClean:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Melody Lam:** Methodology, Data curation, Formal analysis, Writing – review & editing, Project administration. **Britney Le:** Methodology, Formal analysis, Writing – review & editing. **Teresa To:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'Janice Tijssen reports financial support was provided by Western University'.

Acknowledgements

N/A.

Funding/Support

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health (MOH) and the Ministry of Long-Term Care (MLTC). The study was completed at the ICES Western site, where core funding is provided by the Academic Medical Organization of Southwestern Ontario, the Schulich School of Medicine and Dentistry, Western University, and the Lawson Health Research Institute. This study also received funding from Western Strategic Support Seed Grant (Western University). This document used data adapted from the Statistics Canada Postal CodeOM Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada. Parts of this material are based on data and/or information compiled and provided by CIHI, MOH, and OH. The analyses, conclusions, opinions and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2023.100442.

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