

Original Article

Urban-Rural Differences in Cardiac Arrest Outcomes: A Retrospective Population-Based Cohort Study

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ABSTRACT

Background: Approximately 10% of people who suffer an out-of-hospital cardiac arrest (OHCA) treated by paramedics survive to hospital discharge. Survival differs by up to 19.2% between urban centres and rural areas. Our goal was to investigate the differences in OHCA survival between urban centres and rural areas.

Methods: This was a retrospective cohort study of OHCA patients treated by Nova Scotia Emergency Medical Services (EMS) in 2017. Cases of traumatic, expected, and noncardiac OHCA were excluded. Data were collected from the Emergency Health Service electronic patient care record system and the discharge abstract database. Geographic information system analysis classified cases as being in urban centres (population > 1000 people) or rural areas, using 2016 Canadian Census boundaries. The primary outcome was survival to hospital discharge. Multivariable logistic regression covariates were

RÉSUMÉ

Contexte : Environ 10 % des personnes qui subissent un arrêt cardiaque en milieu extrahospitalier (ACEH), traité par des intervenants paramédicaux, survivent jusqu'à leur congé de l'hôpital. Le taux de survie peut différer de 19,2 % entre les centres urbains et les régions rurales. Notre étude visait à étudier les différences en matière de survie après un ACEH entre les centres urbains et les régions rurales.

Méthodologie : Il s'agissait d'une étude de cohorte rétrospective portant sur des patients ayant subi un ACEH traité par les services médicaux d'urgence de la Nouvelle-Écosse en 2017. Les cas d'ACEH traumatique, prévu et non cardiaque ont été exclus. Les données ont été recueillies à partir du système de dossiers électroniques de soins aux patients des services médicaux d'urgence et de la Base de données sur les congés des patients. L'analyse du système d'information géographique a classé les cas selon qu'ils sont survenus dans

Out-of-hospital cardiac arrest (OHCA) affects 50,000 Canadians each year, and in North America, only 11.4% of treated patients survive to hospital discharge.^{1,2} Factors that lead to

survival disparities among regions include variations in socio-economics, urban planning, bystander recognition, emergency response, automatic external defibrillator (AED) distribution and utilization, bystander cardiopulmonary resuscitation (CPR), and advanced care quality.³⁻⁶ These factors are intertwined with the chain of survival, comprised of the following: early recognition of the cardiac arrest and patient access, early CPR and defibrillation, early advanced care life support, and aggressive postresuscitation care.⁷⁻⁹

Geospatial factors, such as response time and AED distribution, play a critical role.^{10,11} Delays in emergency medical service (EMS) response decrease survival probability by about

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Ethics Statement: The Nova Scotia Health (NSH) research ethics board approved this research (REB # 1024741).

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See page 388 for disclosure information.

age, sex, bystander resuscitation, whether the arrest was witnessed, public location, and preceding symptoms.

Results: A total of 510 OHCA treated by Nova Scotia Emergency Medical Services were included for analysis. A total of 12% (n = 62) survived to discharge. Patients with OHCA in urban centres were 107% more likely to survive than those with OHCA in rural areas (adjusted odds ratio = 2.1; 95% confidence interval = 1.1 to 3.8; P = 0.028). OHCA in urban centres had a significantly shorter mean time to defibrillation of shockable rhythm (11.2 minutes ± 6.2) vs those in rural areas (17.5 minutes ± 17.3).

Conclusions: Nova Scotia has an urban vs rural disparity in OHCA care that is also seen in densely populated OHCA centres. Survival is improved in urban centres. Further improvements in overall survival, especially in rural areas, may arise from community engagement in OHCA recognition and optimized healthcare delivery.

5% per minute.^{12,13} Delays in defibrillation of ventricular fibrillation (VF) decrease survival by 10% per minute. For this reason, early bystander AED use increases the odds of survival to > 50%.^{14,15}

These factors are highlighted in research on OHCA in relation to rurality. Rurality compounds the challenge of providing optimal care, because of low population density, societal ageing, and increased distances from healthcare resources. These factors may contribute to disparities in outcomes.¹⁶ Urban-rural characteristics critical to survival are also region-specific, with significant variation in bystander response rates and AED usage. Urban and rural survival-to-discharge rates vary by as much as 9.3% within the catchment area of a tertiary care site, and 19.2% among different sites.^{11,16-20} This degree of variation suggests that an understanding urban-rural OHCA differences by region is needed.

Most epidemiologic studies on OHCA describe heterogeneity in populations and healthcare systems, but they consistently include densely populated urban areas. Descriptions of patients suffering cardiac arrest in low-density or rural populations are sparse. This study aims to characterize cardiac arrests in a single-provider EMS healthcare system that spans both urban and rural geographies, and describe characteristics of rural and urban OHCA patients in order to identify opportunities for improvement.

Methods

Study design and setting

This was a retrospective cohort study, including the entire population of Nova Scotia (population 923,598 as of the 2016 census). The province is served by a single EMS provider. Paramedics in Nova Scotia respond to more than 1200 cardiac arrests per year. The ground ambulance service is

un centre urbain (population de plus de 1 000 personnes) ou dans une région rurale, en utilisant les limites du recensement canadien de 2016. Le principal paramètre d'évaluation était la survie à la sortie de l'hôpital. Les covariables utilisées dans la régression logistique multivariée étaient l'âge, le sexe, la réanimation effectuée par des témoins si présents lors de l'arrêt cardiaque, l'emplacement public et les symptômes précédents.

Résultats : Au total, 510 ACEH traités par les services médicaux d'urgence de la Nouvelle-Écosse ont été inclus aux fins de l'analyse. En tout, 12 % (n = 62) des sujets ont survécu jusqu'à leur congé hospitalier. Les patients ayant subi un ACEH dans un centre urbain étaient 107 % plus susceptibles de survivre que ceux ayant subi un ACEH dans une région rurale (rapport de cotes ajusté : 2,1; intervalle de confiance à 95 % : 1,1 – 3,8; p = 0,028). Le temps moyen de délivrance d'un choc lors d'un ACEH avec rythme défibrillable est significativement plus court (11,2 ± 6,2 minutes) dans un centre urbain que dans une région rurale (17,5 ± 17,3 minutes).

Conclusions : La Nouvelle-Écosse fait état d'une disparité dans les soins de l'ACEH entre les régions urbaines et les régions rurales, que l'on observe également dans les villes densément peuplées. La survie est plus longue dans les centres urbains. Il est possible de prolonger davantage la survie globale, en particulier dans les régions rurales, en sensibilisant la communauté à l'ACEH et en optimisant la prestation des soins de santé.

comprised of primary, intermediate, advanced care, and critical care paramedics. The paramedic response is supported by a provincial system of volunteer fire-based medical first response. The province is characterized by a mix of urban, suburban, and rural regions, with a median population density of 61.5 people per square kilometre, and a mean of 17.4 people per square kilometre. The provincial capital, Halifax, is the most population-dense part of the province, with a median population density of 2,785 people per square kilometre. The Nova Scotia Health (NSH) research ethics board approved this research (REB # 1024741).

Study participants

Consecutive Nova Scotia EMS responses for OHCA from January 1st to December 31st, 2017 were identified via electronic query within the electronic patient care record (ePCR) system via keywords recorded by dispatchers and on-scene paramedics. Cases were selected if OHCA was indicated based on the dispatch determinant, chief complaint, or paramedic-documented clinical impression. Other fields indicating OHCA were searched, including the use of interventions (eg, electrical therapy, amiodarone, epinephrine, etc), CPR, AED use, estimated time of cardiac arrest, pronouncement of death, or by-rhythm analysis (eg, asystole, VF). Paramedics complete an ePCR on all patient encounters.

Inclusion criteria were as follows: All OHCA calls for which the EMS attempted resuscitation were included. Exclusion criteria were as follows: Cases were excluded if they were an obvious death or a cardiac arrest within the emergency department (ED) or in-hospital unit, if a "do not resuscitate" advance directive was identified, or if they were an expected death with EMS activation but no resuscitation attempted (eg, palliative care), a noncardiac cause (eg, overdose, drowning), or a traumatic arrest.

Data sources

Data were collected from the Medusa Siren Version 3 ePCR system (Nova Scotia Department of Health & Wellness), and from the discharge abstract database electronically accessed through Nova Scotia Health. The ePCR free-text narrative was reviewed by 3 trained researchers, and data were abstracted using prespecified data definitions based on Utstein criteria. During abstractor training, all charts were reviewed by M.C., and then 20% of subsequent records were reviewed to ensure consistency with the data abstraction.

Outcome measures

The primary outcome was survival to hospital discharge. The relationship between Utstein process elements (response time and defibrillation) and survival was used to assess urban-rural differences^{7,21,22}

Data analysis

Population-centre definition. The use of publicly available 2016 census data co-opts the Canadian census definition of a population centre as an area with at least 1000 people and a population density of 400 persons or more per square kilometre. Rural areas are classified as all areas that are outside of population centres.^{23,24} Briefly, population-centre boundaries are delineated using the spatial unit of “dissemination areas,” and a population centre is continuous when it is adjacent to other population centres that are less than 2 kilometres away by road.²⁴

Population-centre classification. Population centres are classified to reflect the rural-urban continuum, as follows: small (1000 to 29,999 people); medium (30,000 to 99,999 people); and large urban (100,000 people or more). According to this classification, Nova Scotia contains 36 small population centres and 1 large urban population centre (Halifax), see [Supplemental Appendix](#).

Rurality determination. The latitude and longitude of each site of cardiac arrest were available within the electronic record and were used to classify the setting as urban or rural, using QGIS (version 3.10; <https://qgis.org>) open-source mapping software. The “population centre polygon shapefile” was used to categorize locations of OHCA according to whether or not they occurred within (urban) or outside of (rural) a population centre.²⁵

Distance from OHCA to an AED or a hospital. OHCA locations were input into the QGIS (3.10) distance matrix tool, with coordinates for either an AED or hospital. The output of the minimum straight-line distance between the site of OHCA and an AED or hospital was recorded in metres. The ePCRs with missing or erroneous latitude and longitude coordinates ($n = 16$) were generated, and then backfilled using 911-dispatch street addresses geocoded to latitude and longitude using a custom-built geocoder in ArcGIS software (10.8.1; Esri Canada, Toronto, ON). Missing latitude and longitude data ($n = 2$) were excluded from the continuous-variable analysis; see [Supplemental Appendix](#).

Statistical analysis

Multivariable logistic regression was performed using SAS (version 9.4; SAS Institute Inc, Cary, NC) with rurality exposure and an outcome of survival to discharge. Utstein core patient covariates of age, sex, bystander resuscitation, witness status, private or public location, and preceding symptoms were included in the model in order to normalize the subgroups.⁷ Time-dependent covariates thought to be part of the causal pathway of rural OHCA were excluded from regression analysis. These covariates included the following: first-monitored rhythm, response time, time to defibrillation, and time to I-V access. Results are presented as odds ratios (ORs) and 95% confidence intervals (CIs). GraphPad Prism software (version 8.0; GraphPad, San Diego, CA) calculated the Fisher’s exact test for categorical variables, and the Mann-Whitney U test was performed on continuous variables with mean and standard deviation (SD). Significance was defined as $P < 0.05$.

Results

Characteristics of study participants

Of the 1517 OHCA identified, 488 met the exclusion criteria ([Fig. 1](#)). A total of 519 OHCA of presumed cardiac origin were not treated by paramedics. Most untreated patients met obvious death criteria (eg, prolonged pre-arrival time, signs of rigor mortis), but 8 patients had treatment withdrawn due solely to prolonged pre-arrival time. Of the 511 obvious deaths, the majority of patients had no contact with bystanders for more than 12 hours prior to pronouncement of death ([Supplemental Table S1](#)). The Utstein elements of study cohort and subgroups divided by location are shown in [Table 1](#).

Paramedic response

Paramedic response time, from the 911 call to paramedic arrival, was significantly shorter in urban centres, compared with rural areas (7.8 vs 13.4 minutes; $P < 0.001$). Paramedics attempted resuscitation in 510 cases, and the estimated time to defibrillation of VF/ventricular tachycardia (VT) from the 911 call to the administration was significantly shorter in urban centres, compared with rural areas (11.2 vs 17.5 minutes; $P < 0.001$; [Table 1](#)). Subgroup analysis of initially shockable (VF/VT) patients shows that the proportion of VF/VT patients achieving return of spontaneous circulation (ROSC) is significantly higher in urban centres ($P < 0.001$). The number of patients achieving any ROSC or surviving to transport was significantly higher in urban centres ($P = 0.0073$, and $P < 0.001$, respectively).

Patient outcomes

Survival to discharge occurred in 62 cases provincially (12.2%; [Table 1](#)). The odds of survival for paramedic-treated patients in urban centres were higher, compared with those in rural areas (OR: 1.9, 95% CI 1.1-3.4; $P = 0.026$). With the adjusted model, paramedic-treated patients still had significantly increased odds of survival (OR 2.1, 95% CI 1.1-3.8) in urban centres, compared with rural areas ([Table 2](#)). Of the patients who survived to discharge, 69% were discharged home ([Fig. 1](#)).

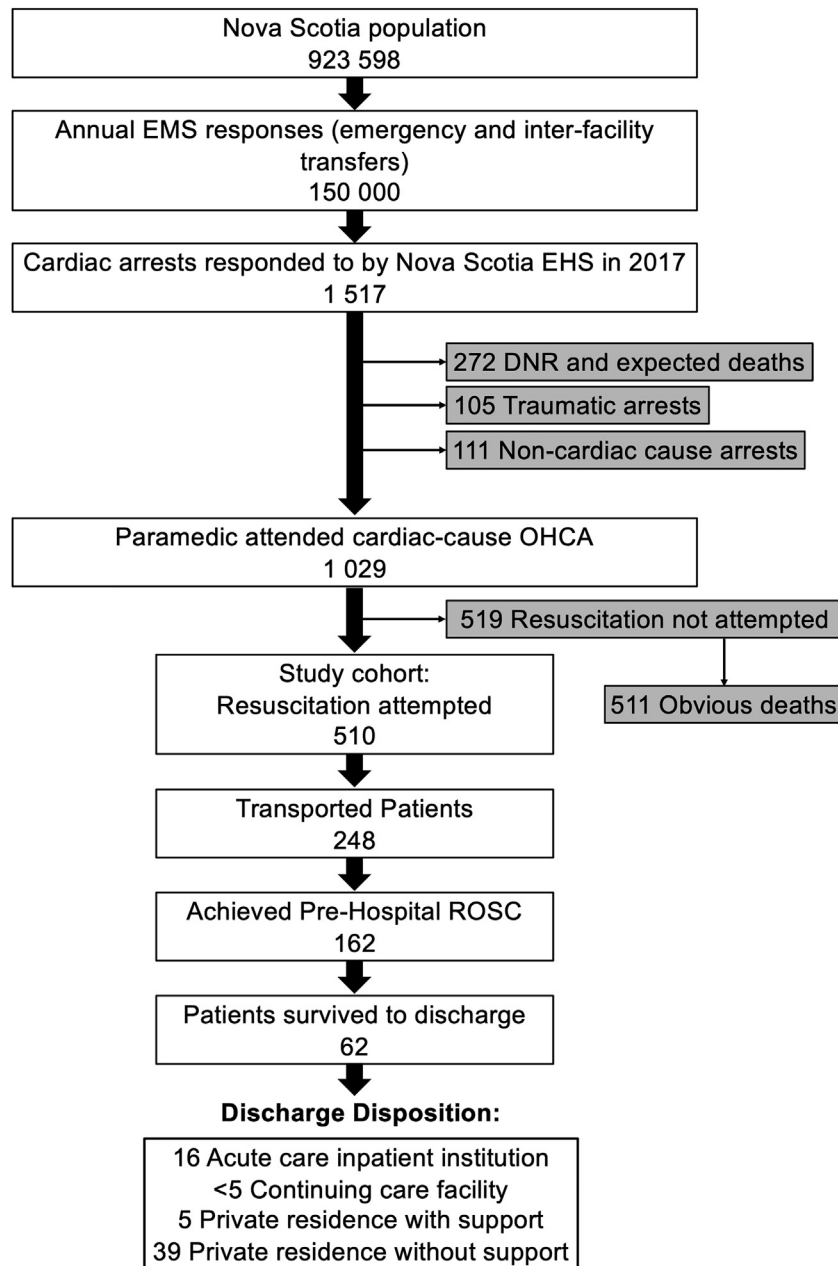


Figure 1. Study flow of system Utstein elements. Numbers listed are the patients included in each group. A total of 510 patients were treated by emergency health services (EHS) paramedics and categorized by clinical outcome. DNR, do not resuscitate; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation.

Geospatial differences

The distance to the nearest publicly registered AED was significantly lower in urban centres compared with rural areas (1 215 vs. 7 850 metres; $p < 0.001$), as was the distance to the nearest hospital (4913 vs 16,077 metres; $P < 0.001$; Table 1).

Discussion

We describe disparities in survival outcomes in a provincial EMS system comprised of urban and rural communities, and

with low provincial population density. This study is the first in Canada to observe a significant increase in odds of OHCA survival in urban centres, compared with that in rural areas. In this provincial system, the rate of survival to hospital discharge (12%) was comparable to that in other systems. Factors occurring before paramedic arrival (eg, bystander CPR) and after paramedic arrival (eg, time to intervention) both influence survival. Process factors may be involved, as the proportion of shockable rhythms resulting in ROSC is significantly higher in urban areas. The 6-minute delay in delivery of shock may be significant in achieving ROSC.

Table 1. Utstein elements of Nova Scotia treated out-of-hospital cardiac arrests in 2017

| | Urban centre n = 286 | Rural area n = 224 | P | All n = 510 |
|--|-------------------------|-----------------------|--------|----------------|
| Demographics | | | | |
| Mean age, y (SD) | 65.5 (17.1) | 67.5 (13.5) | 0.30 | 66.4 (15.7) |
| Male sex | 184 (64.3) | 163 (72.8) | 0.04 | 347 (68.0) |
| Public arrest location | 29 (10.1) | 27 (12.1) | 0.57 | 56 (11.0) |
| Preceding symptoms* | 134 (46.9) | 121 (54.0) | 0.13 | 255 (50.0) |
| Witnessed OHCA | 178 (62.2) | 143 (63.8) | 0.78 | 321 (62.9) |
| Bystander CPR | 174 (60.8) | 123 (54.9) | 0.21 | 297 (58.2) |
| Bystander AED use | 12 (4.2) | 7 (3.1) | 0.64 | 19 (3.7) |
| Nearest public AED (n = 508), metres, mean (SD) [‡] | 1216 (1431) | 7848 (6337) | < 0.01 | 4114 (5431) |
| Mean response time, min (SD) | 7.8 (4.4) | 13.4 (7.0) | < 0.01 | 10.2 (6.3) |
| Shockable rhythm (VF/VT) upon EMS arrival | 81 (28.3) | 54 (24.1) | 0.3 | 135 (26.5) |
| Mean time to VF/VT defibrillation (n = 130), min (SD) | 11.2 (6.2) | 17.5 (17.3) | < 0.01 | 14.0 (10.9) |
| VF/VT and any ROSC | 50 (61.7) | 21 (38.9) | 0.01 | 71 (52.6) |
| VF/VT and survived to hospital discharge | 25 (30.9) | 9 (16.7) | 0.07 | 34 (25.2) |
| Any ROSC | 105 (36.7) | 57 (25.5) | < 0.01 | 162 (31.8) |
| Survived to transport | 166 (58.0) | 87 (38.8) | < 0.01 | 253 (49.6) |
| Nearest hospital (n = 508), metres, mean (SD) [‡] | 4913 (4563) | 16,161 (11,937) | < 0.01 | 9828 (10,265) |
| Survived to hospital discharge | 43 (15.0) | 19 (8.5) | 0.03 | 62 (12.2) |

Values are count (percentage of column total), unless otherwise indicated. Fisher's exact test was performed for frequency distribution. Mann-Whitney test was used for comparison of continuous variables between urban-centre and rural-area subgroups.

AED, automatic external defibrillator; CPR, cardiopulmonary resuscitation; EMS, (Nova Scotia) Emergency Medical Services; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; SD, standard deviation; VF, ventricular fibrillation VT, ventricular tachycardia.

* Presence of preceding/premonitory symptoms were identified from free-text field notes of paramedics.

[‡] Distance measured as a straight line in metres.

In this study, the rate of survival to discharge was 12.2% for patients treated by EMS. This rate is between the rates of survival reported by the Resuscitation Outcomes Consortium (ROC) sites of Toronto (9.4%) and Vancouver (14.9%), but in a provincial system. Nova Scotia has a lower population density than the Toronto metro area and the Vancouver metro area (mean population densities of 17,351, and 619 people per square kilometre, respectively). The demographic, public OHCA location, and witness status characteristics were similar between sites.^{2,26,27} OHCA is a low-frequency event in Nova Scotia, so paramedics may have less experience managing these types of calls. Overall OHCA survival in Nova Scotia is similar to that in larger, more population-dense Canadian sites.

In the first direct comparison of urban and rural OHCA outcomes in Canada, the OHCA survival rate in Nova Scotia urban centres is 6.6% higher than that in rural areas. Internationally, survival from OHCA is also higher in urban centres, compared with rural areas (9.7% in the greater

Stockholm area, 3.7% in Japan, and 10% in Taiwan).^{11,14,16}

Nova Scotia is distinct from international sites because it has a lower population density, and the closest comparator, the greater Stockholm area (mean population density of 322 people per square kilometre), remains more similar to Vancouver. The differences in survival between urban centres and rural areas in a less-dense Nova Scotia OHCA population remain similar to those in more population-dense centres.

We observed a significant urban-rural difference in temporal relationships driven by the lower population density in rural Nova Scotia, compared with that in sites in the literature. Mean EMS response time in Nova Scotian urban centres (7.8 minutes, SD 4.4) are similar, but more variable, compared with both Toronto (6.4 minutes, SD 3.24) and Vancouver (6.5 minutes, SD 1.5). Mean EMS response times in rural Nova Scotia (13.4 minutes, SD 7.0) are longer and more variable compared to those in rural Ontario (12.3 minutes, SD 5.8).^{2,26,28}

Table 2. Multivariable logistic regression analysis of out-of-hospital cardiac arrests in urban centres, and survival to discharge

| Survival to discharge | Paramedic-treated patients | | | | | | |
|--|----------------------------|----------|------------|-------|-------------|------------|-------|
| | N | Crude OR | 95% CI | P | Adjusted OR | 95% CI | P |
| Urban centre vs rural area | 510 | 1.91 | 1.08, 3.38 | 0.026 | 2.07 | 1.11, 3.85 | 0.028 |
| Large urban centre vs population centres and rural areas | 510 | 1.97 | 1.14, 3.41 | 0.015 | 2.11 | 1.17, 3.82 | 0.029 |

Adjusted model used covariates of age, sex, bystander resuscitation, witness status, public vs non-public location, and presence of preceding symptoms. Rural areas have populations of < 1000 people. Urban centres have populations of ≥ 1000 people. Large urban centres have populations of ≥ 100,000 people. OR, odds ratio; CI, confidence interval.

This delay in rural OHCA care may weaken the chain of survival. Although the OHCA in urban centres and rural areas had similar rates of shockable rhythm, OHCA in rural areas had less VF/VT defibrillation resulting in ROSC. Delayed rural EMS response in Nova Scotia precipitated significantly increased mean time to VF/VT defibrillation (17.2 minutes), compared with that in urban centres, where observed mean times are in line with the North American mean (10.8 minutes).¹ In this first province-wide assessment, AEDs were not accessible to Nova Scotian OHCA bystanders, exceeding the recommended 100 metres in both urban and rural settings.^{29,30} Taken together, these process factors suggest that the absence of early defibrillation of shockable rhythms in rural areas contributes to worse OHCA outcomes.

The significant decrease in the number of VF/VT patients achieving ROSC in rural areas, compared with urban centres, alongside a significant delay in time to defibrillation, supports the use of AED by bystanders. Opportunities for improvement could focus on the targeted expansion of provincial AED network programs, improved training and support for medical first-response services, and innovative drone AED-delivery technology. The lack of accessible AEDs in OHCA locations in both urban and rural centres highlights an opportunity for AED delivery by drone, in order to minimize time to defibrillation. In rural Ontario, drone response times were up to 8 minutes faster than those of the EMS in rural areas. More than 75% of Nova Scotia OHCA could be within the 25-kilometre range of a hospital-stationed drone and may benefit from drone AED delivery.²⁸ Specifically, rural Nova Scotia could most benefit from drone AED delivery, to shorten the time to defibrillation of VF/VT rhythms, increase the number of patients who achieve ROSC, and strengthen the chain of survival.

Limitations and future directions

Assessment of patient factors was limited by the lack of in-hospital treatment information and inter-rater reliability within retrospective clinical datasets. We are unable to account for variability in patient characteristics or hospital interventions that may affect the difference in survival to hospital discharge between urban centres and rural areas. The degree to which these unmeasured or unmeasurable factors may have influenced these observations is uncertain. Other differences between urban and rural populations may have had influences on health outcomes. The Canadian Census dataset is limited by the delineated boundary lines of the official dissemination areas for determination of urban/rural classification. Separately, the use of straight-line distance may underestimate distance travelled in the real world. We do not have detailed data on whether AEDs used by bystanders were from the pool of 336 public-access AEDs registered in 2017, and the data are insufficient to determine if distance from an AED is correlated with its usage. The AED registry was established in only 2017 and thus underrepresents actual AED availability in 2017.

More sophisticated geospatial analyses could be employed to better understand geographic, temporal, and seasonal effects on rural OHCA outcomes. Network-based distance calculations, if they were created, would better approximate the distance an individual would have to travel for help and would be better able to assess the relationship between

population density and OHCA survival. Drive-time polygons would also account for other features of road networks in the future. In the future, fly-time polygons for AED delivery by drone could show how Nova Scotia's geography facilitates cost-effective scalable implementation of a drone AED-delivery network.

Conclusion

The disparity in urban-rural OHCA care seen in high-population density centres is also observed in low-population density regions. Although the survival rate is higher in urban centres, the time delays and spatial barriers to treatment we observed in rural areas may negatively influence survival. Improvements in the overall survival rate may result from optimal community engagement in OHCA recognition, high-quality bystander CPR, and optimal deployment of healthcare resources in rural areas.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at <https://www.cjcopen.ca/> and at <https://doi.org/10.1016/j.cjco.2021.12.010>.