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Original Article

Incidence and Outcomes of Out-of-Hospital Cardiac Arrest Patients Admitted to the Hospital in Canada from 2013 to 2017

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Study Design — Population-based retrospective cohort study

Population — Non-traumatic OHCA patients aged 2-85 years who were admitted to the hospital

Setting — Canada (9 provinces and 3 territories)

Objective — Evaluate geographical differences in incidence and outcomes from 2013-2017

Main Findings

- ✓ Overall age- and sex-standardized incidence of OHCA patients admitted to the hospital in Canada was 8.3 per 100,000 population per year.
- ✓ Incidence was highest in British Columbia, Manitoba, and Nova Scotia, whereas lowest in New Brunswick, Prince Edward Island, and Saskatchewan (Figure 1).
- ✓ The proportion of OHCA patients who survived to hospital discharge was highest in Prince Edward Island and lowest in Ontario, with a national average of 43% (Figure 2).
- ✓ No significant trend in survival to hospital discharge was observed from 2013 (43%) to 2017 (42%; p=0.86).

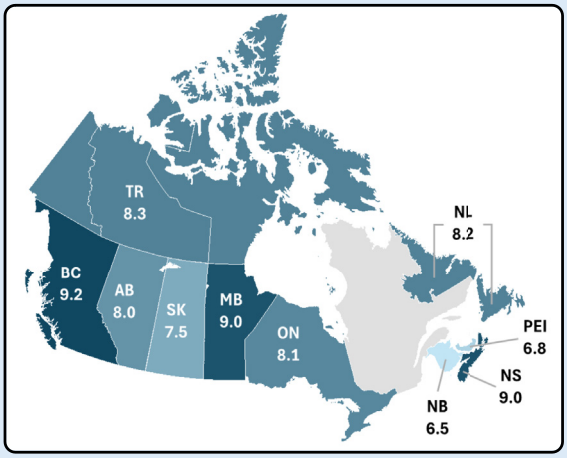

Figure 1. Age- and sex-standardized incidence (per 100,000 per year) of OHCA patients admitted to the hospital according to region.

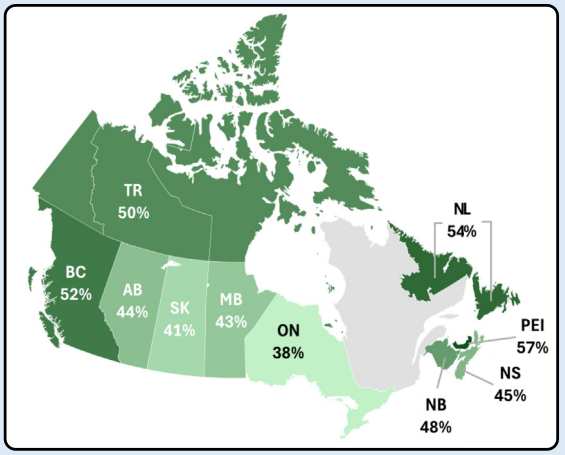

Figure 2. Proportion of OHCA patients admitted to the hospital who survived to hospital discharge.

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ABSTRACT

Background: Out-of-hospital cardiac arrest (OHCA) remains a prominent medical concern worldwide. Epidemiologic metrics and trends over time for OHCA cases in Canada are not well defined. This study evaluated geographic differences in the incidence and outcomes of OHCA patients admitted to hospitals across Canada, during the period 2013-2017.

Methods: This population-based retrospective cohort study included 10,492 nontraumatic OHCA patients aged 2-85 years (66% male) who were admitted to an acute-care hospital in any Canadian province or territory (excluding Quebec) between 2013 and 2017. Overall age- and sex-standardized incidence measures (per 100,000 population per year) were calculated through direct standardization to the 2016 Canadian population. Temporal trends in incidence and survival to hospital discharge were evaluated.

Results: The overall age- and sex-standardized incidence of OHCA patients admitted to the hospital was 8.3 per 100,000 population per year, which did not change significantly from 2013 to 2017 (incidence rate ratio: 1.01, 95% confidence interval: 0.99-1.02). The incidence was highest in British Columbia (9.2 per 100,000 population per year), Manitoba (9.0 per 100,000 population per year), and Nova Scotia (9.0 per 100,000 population per year), and lowest in New Brunswick (6.5 per 100,000 population per year), Prince Edward Island (6.8 per 100,000 population per year), and Saskatchewan (7.5 per 100,000 population per year). The proportion of OHCA patients who survived to hospital discharge was highest in Prince Edward Island (57%) and lowest in Ontario (38%). No significant trend in rates of survival to hospital discharge was observed from 2013 (43%) to 2017 (42%; $P = 0.86$).

Conclusions: The age- and sex-standardized incidence of OHCA patients admitted to the hospital, and their survival outcomes, were stable in Canada from 2013 to 2017, with considerable variation noted across geographic regions.

RÉSUMÉ

Contexte : L'arrêt cardiaque extrahospitalier (ACEH) demeure un problème médical très important partout dans le monde. Les paramètres et les tendances épidémiologiques dans le temps en ce qui concerne les cas d'ACEH au Canada ne sont pas bien définis. Cette étude visait à évaluer les différences géographiques dans l'incidence et les résultats des patients ayant subi un ACEH admis dans les hôpitaux au Canada, durant la période de 2013 à 2017.

Méthodologie : Cette étude de cohorte rétrospective dans la population comportait 10 492 patients ayant subi un ACEH non traumatique âgés de 2 à 85 ans (66 % de sexe masculin) ayant été admis dans un hôpital de soins de courte durée dans une province (excluant le Québec) ou un territoire au Canada entre 2013 et 2017. L'incidence globale normalisée en fonction de l'âge et du sexe (par 100 000 habitants par an) a été calculée par une normalisation directe à la population canadienne de 2016. Des tendances temporelles de l'incidence et de la survie jusqu'au congé de l'hôpital ont été évaluées.

Résultats : L'incidence globale normalisée en fonction de l'âge et du sexe des patients ayant subi un ACEH admis à l'hôpital était de 8,3 par 100 000 habitants par an, ce qui n'a pas changé de manière significative entre 2013 et 2017 (rapport du taux d'incidence : 1,01; intervalle de confiance à 95 % : 0,99-1,02). L'incidence la plus élevée étaient en Colombie-Britannique (9,2 par 100 000 habitants par an), au Manitoba (9,0) et en Nouvelle-Écosse (9,0); la moins élevée, au Nouveau-Brunswick (6,5), à l'Île-du-Prince-Édouard et en Saskatchewan (7,5). La proportion de patients hospitalisés pour un ACEH qui ont survécu jusqu'au congé de l'hôpital était la plus élevée à l'Île-du-Prince-Édouard (57 %) et la plus basse en Ontario (38 %). Aucune tendance notable en ce qui concerne le taux de survie jusqu'au congé de l'hôpital n'a été observée entre 2013 (43 %) et 2017 (42 %; $p = 0,86$).

Conclusions : Le taux d'hospitalisations pour ACEH normalisé en fonction de l'âge et du sexe, et la survie, a été stable au Canada entre 2013 et 2017, une variation considérable étant observée entre les régions géographiques.

Out-of-hospital cardiac arrest (OHCA) is an important public health issue worldwide, which can devastate families, friends, and entire communities.[1-4] The estimated annual incidence of OHCA that is treated by emergency medical services (EMS) is in the range of 30.0-97.1 individuals per 100,000 population globally.[1] In most developed countries, the proportion of OHCA patients who survive to hospital discharge is well below 15%.[1,5] Recent 2017 estimates from the Canadian Resuscitation Outcomes Consortium (CanROC) registry have calculated an incidence of 93.3 per 100,000 population for all EMS-assessed cases of OHCA, of which only 10% of individuals survive to hospital discharge.[6]

Over the past 2 decades, treatment advances for OHCA primarily have targeted the improvement of resuscitation interventions performed by bystanders and professional responders.[7-12] Despite substantial global investments, only modest increases in the rate of overall survival have occurred in many regions, including North America,[13,14] Asia,[15,16] and Europe.[17,18] Approximately 75% of all OHCA patients die as a result of the event, either on scene or in the emergency department (ED).[19] However, care for the patients who survive to hospital admission accounts for the majority of the healthcare costs and resource utilization associated with OHCA in Canada.[19]

From 1994-2004, the annual incidence of OHCA patients admitted to hospitals decreased by 33% in Canada, yet the proportion of these patients who survived to hospital discharge did not change over this 10-year period.[20] Other work has demonstrated minimal improvements in outcomes for OHCA patients who were admitted to the hospital from 2002-2012 within Canada's largest province, Ontario.[14,21] At present, there is a paucity of updated evidence on the epidemiology of OHCA patients who survive to hospital admission in Canada. Moreover, recent national temporal trends in the

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See page 97 for disclosure information.

incidence and outcomes of OHCA patients who survive to hospital admission are largely unknown.

Guidelines from national and international medical societies, including the Canadian Cardiovascular Society (CCS) and the International Liaison Committee on Resuscitation (ILCOR), have highlighted evidence-based care recommendations for this subset of the OHCA population.[22,23] Therefore, there is an urgent need to better understanding the outcomes of OHCA patients admitted to hospitals across Canada, which may provide insights into the quality and timeliness of care provided by in-hospital healthcare practitioners. These data are necessary to refocus health-resource allocation and public health efforts. Accordingly, the objective of this study was to describe the incidence and outcomes of OHCA patients admitted to the hospital across regions in Canada, during the period 2013-2017, using population-based health administrative datasets.

Methods

The reporting of this study was guided by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist.[24] Data used in this study were collected under a waiver of consent from the Canadian Institute for Health Information (CIHI). This study was approved by the Unity Health Toronto Research Ethics Board (REB #18-146).

Data source

The data used for this study were obtained from CIHI, which collects comparable, pan-Canadian data (excluding Quebec) on different aspects of the healthcare system for research, performance evaluation, and quality-improvement purposes.[25] Specifically, the CIHI Discharge Abstract Database (DAD), which contains demographic, administrative, and clinical information on inpatient hospitalizations at acute-care facilities across Canada, was used to identify OHCA patients who were admitted to acute-care hospitals.[26] This comprehensive database also provided information on patient characteristics, comorbidities, clinical procedures, and vital statistics at discharge for all OHCA cases included in the study. As a result, the target population of this study was OHCA patients who were admitted to the hospital in Canada. All processes related to the submission, verification, and cleaning of data are managed and executed by CIHI, in compliance with their Information Quality Framework.[27] Data analyses were performed by the study investigators, without any involvement from CIHI.

Study design and setting

This population-based retrospective cohort study consisted of nontraumatic OHCA patients who were admitted to an acute-care hospital in any 1 of the 12 included Canadian provinces or territories, between January 1, 2013 and December 31, 2017. All eligible patients were transported via ambulance to an ED, after which they were transferred and admitted alive as inpatients within an acute-care hospital.

The Canadian provinces (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, and Saskatchewan) and territories (Northwest Territories, Nunavut, and Yukon) captured in this study covered a catchment population of 26,987,367, and a land area of 7,608,864 square kilometers (2016 estimates).[28] Due to provincial authorization restrictions, data from Quebec were not available for inclusion in this study. Nonetheless, as the province of Quebec does not mandate the reporting of clinical data in the DAD, the inclusion of such data would have undercounted the number of OHCA patients admitted to the hospital for this province.[29]

Study cohort

The source population consisted of all patients aged 2-85 years who were admitted to an acute-care hospital with a diagnosis code in their record that was indicative of OHCA. To provide surveillance data on a clinically relevant population, we excluded patients aged < 2 years, to avoid including cases of sudden infant death syndrome,[30] and those aged ≥ 85 years, due to their extremely low survival rates following an OHCA.[31-33] An OHCA was identified in the DAD using the *International Classification of Diseases, Tenth Revision* (ICD-10) codes for cardiac arrest (I46.0, I46.1, I46.9, I49.00, I49.01, R96.0, R96.1, R98, R99; see Supplemental Table S1 for descriptions); this algorithm has been used previously by Wong et al.[21] These ICD-10 codes have a high level of sensitivity and positive predictive values for identifying cardiac arrest in health administrative databases within Canada and other countries for both pediatric and adult OHCA cases.[34,35] The ICD-10 code for cardiac arrest was required to be entered in the patient record, either as the diagnosis most responsible for the admission or a preadmission comorbidity; this approach ensured that no *probable* in-hospital cardiac arrests were included in the source population. Previous research has used the Canadian Classification of Health Interventions codes for cardiopulmonary resuscitation to identify cardiac arrest cases (1HZ30JN and 1HZ30JY)[21]; however, determining whether the arrest occurred in or out-of-hospital is not possible in the absence of an ICD-10 code. Thus, we only used ICD-10 codes to identify the source population, as a means to avoid misclassification of in-hospital arrests as OHCAs.

To determine the study cohort, the following exclusions were applied. Planned readmissions, and admissions with an inappropriate discharge disposition (ie, the patient left the hospital before a formal discharge vital status was ascertained), were excluded. Any patients whose records included a trauma diagnosis code also were excluded, with the assumption that these OHCAs were attributed to life-threatening trauma (Supplemental Table S2). Only the first event was included for patients who had multiple arrests throughout the study period.[36] Details on the process of generating the source population from the DAD, and relevant exclusions used to determine the study cohort, are described in Supplemental Appendix 2. The cohort-selection flowchart is described in Figure 1. The index date was defined as the date of hospital admission.

Variables

Patient characteristics included age, sex, hospital length-of-stay, and location of residence (urban or rural, derived from the patient's postal code using Statistics Canada's Postal Code Conversion File). Hospital type was divided into the following

categories: teaching hospitals; large community hospitals; medium community hospitals; and small community hospitals (see Supplemental Table S3 for definitions). Historical clinical characteristics, which included comorbidities, previous procedures, and previous hospitalizations, were captured in the DAD, using a 5-year lookback window from the index date of each OHCA. Patient comorbidities included the following: atrial fibrillation; cancer; chronic obstructive pulmonary disease; coronary artery disease; diabetes; dyslipidemia; heart failure; hypertension; ST-segment elevation myocardial infarction (STEMI); other myocardial infarction (MI); peripheral artery disease; and renal failure. Procedures included angiography, coronary artery bypass grafting, implantable cardioverter-defibrillator placement, pacemaker placement, and percutaneous coronary intervention. Hospitalizations included all-cause hospitalizations and cardiovascular-related hospitalizations. All diagnosis and intervention codes used to identify patient comorbidities and procedures are described in Supplemental Table S4. Diagnosis codes used to classify cardiovascular-related hospitalizations are described in Supplemental Table S5. The outcome of interest was survival to hospital discharge, which was ascertained according to discharge disposition information.

Statistical analyses

Patient and clinical characteristics of the study cohort were presented according to calendar year (January 1-December 31) and were stratified by province or territory. The proportion of patients who survived to hospital discharge after OHCA was presented according to calendar year and was further stratified by province or territory, age group (in years: 2-18; 19-35; 36-45; 46-55; 56-65; 66-75; and 76-85), and sex (male, female). Continuous variables were summarized as medians with interquartile ranges (IQRs), whereas categorical variables were summarized as counts with percentages. Temporal trends in characteristics and outcomes were evaluated using the Cochrane-Armitage trend test for categorical variables and linear regression for continuous variables (using the year of OHCA as the independent variable).

Crude incidence measures of OHCA patients admitted to the hospital were calculated using population estimates according to age (2-85 years), sex, and province or territory for denominators (as estimated on July 1 of each year).[37] Age- and sex-standardized measures of the incidence of OHCA patients admitted to the hospital were calculated through direct standardization to the 2016 Canadian Census population aged 2-85 years (including all provinces and territories). Population estimates for all denominators and the standard population were obtained through publicly available data tables published by Statistics Canada.[37,38] Incidence measures were reported for Canada (excluding Quebec), individual provinces, and all territories combined (Northwest Territories, Nunavut, and Yukon), as well as stratified by age group and sex. Confidence intervals (CIs) for standardized incidence measures were constructed using the Tiwari modified gamma method, which is recommended when performing direct standardization on sparse data.[39,40]

Multivariable negative binomial regression was used to evaluate the associations of year, province or territory, age group, and sex, with the incidence rate of OHCA patients admitted to the hospital. This modelling approach was selected, rather than simple Poisson regression, owing to the significant overdispersion of count data, as confirmed through a Lagrange multiplier test ($X^2(1) = 16.04$, $P < 0.0001$), thus violating the mean-equal-to-variance assumption.[41] The negative binomial model corrects for overdispersion by incorporating a dispersion component into the variance, thus relaxing this assumption.[42] An offset term of the natural logarithm of the denominator for each observation unit, according to year, province or territory, age group, and sex, was applied in the model. Incidence rate ratios (IRRs) and 95% CIs were estimated. A P-value of < 0.05 was regarded as statistically significant. All analyses were performed using R, version 4.2.1 (R Foundation, Vienna, Austria) and SAS Enterprise Guide, version 7.15 (SAS Institute, Cary, NC).

Results

Study cohort

A total of 10,492 patients with OHCA were admitted to an acute-care hospital in Canada between January 1, 2013 and December 31, 2017. More than 80% of all OHCA patients were admitted to hospitals in Ontario (49%), British Columbia (20%), and Alberta (12%). Most OHCA patients were transported to teaching hospitals (44%) and large, community hospitals (40%).

Patient and clinical characteristics

Patient and clinical characteristics for the study cohort stratified by year are shown in Table 1. Over the 5-year period, the median age of OHCA patients who were admitted to the hospital was 66 years (IQR: 55-75), of which 66% were of male sex. The median hospital length-of-stay was 5 days (IQR: 1-13). Most OHCA patients who were admitted to the hospital resided in urban locations (89%), whereas 47% had $\geq$ 1 comorbidity. Hypertension (28%), diabetes (21%), heart failure (16%), and coronary artery disease (16%) were the most prevalent comorbidities in this cohort. The proportion of patients who underwent a cardiovascular procedure within 5 years before their index OHCA was 14%, whereas 42% were hospitalized for a cardiovascular-related condition within 5 years before their index event. Patients and clinical characteristics for pediatric (aged 2-18 years) and adult (aged 19-85 years) OHCA patients are shown in Supplemental Table S6.

Various temporal trends for comorbidities, prior procedures, and prior hospitalizations emerged among admitted OHCA patients from 2013-2017. The prevalence of atrial fibrillation, chronic obstructive pulmonary disease, coronary artery disease, dyslipidemia, and other types of myocardial infarction demonstrated significant decreasing trends during the period 2013-2017. Additionally, the proportion of patients who had been hospitalized for a cardiovascular-related condition in the 5 years before their index event also decreased, from 43% in 2013 to 39% in 2017 ($P = 0.0007$).

Patient and clinical characteristics of OHCA patients, according to each province or territory, are shown in Supplemental Table S7. Patients admitted to the hospital with OHCA were younger in the territories (aged 54 years), in comparison to those in the provinces (aged 62-68 years). The

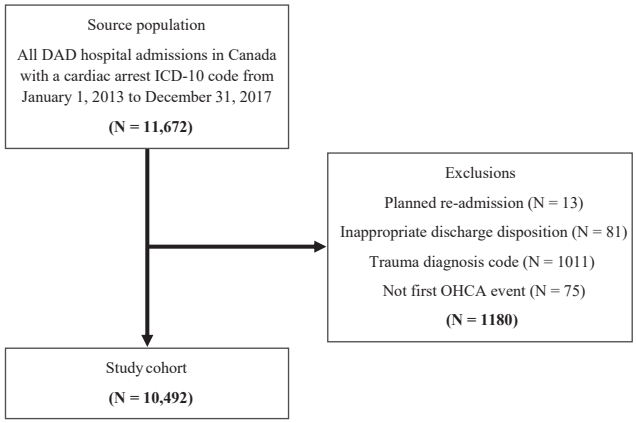

Figure 1. Cohort selection flowchart. DAD, (Canadian Institute for Health Information) Discharge Abstract Database; ICD-10, International Classification of Diseases, Tenth Revision; OHCA, out-of-hospital cardiac arrest.

prevalence of any comorbidity was highest in Manitoba (57%) and Saskatchewan (56%), and lowest in Alberta (43%), British Columbia (43%), and Newfoundland and Labrador (43%). The proportion of patients with a prior cardiovascular procedure was highest in New Brunswick (22%), Prince Edward Island (20%-29%, range provided due to small cell suppression), and Saskatchewan (20%), and lowest in Alberta (10%), Ontario (13%), and the territories ($\leq$ 14%, range provided due to small cell suppression). The proportion of patients who were hospitalized for a cardiovascular-related condition or procedure within 5 years of their index event was highest in Manitoba (52%) and lowest in British Columbia (36%).

Incidence of OHCA patients admitted to the hospital

The crude and age- and sex-standardized incidence measures of OHCA patients admitted to the hospital, by year and stratified by province or territory, are shown in Table 2. The overall age- and sex-standardized incidence of OHCA patients admitted to the hospital in Canada (excluding Quebec) was 8.3 per 100,000 population per year. Among Canadian provinces, the overall age- and sex-standardized incidence, given as number per 100,000 population per year, was highest in British Columbia (9.2), Manitoba (9.0), and Nova Scotia (9.0), and lowest in New Brunswick (6.5), Prince Edward Island (6.8), and Saskatchewan (7.5). The combined age- and sex-standardized incidence of OHCA patients admitted to the hospital for all Canadian territories (Yukon, Northwest Territories, and Nunavut) was 8.3 per 100,000 population per year.

The crude and age- and sex-standardized incidences of OHCA patients admitted to the hospital, by year, and stratified by age group and sex, are shown in Supplemental Table S8. In general, the incidence of OHCA patients admitted to the hospital increased with increasing patient age. Male patients also had a 2-fold higher incidence than did female patients, across the study period.

According to the negative binomial regression model results in Table 3, the incidence rate of of OHCA patients admitted to the hospital did not significantly change during the period 2013-2017 (IRR: 1.01, 95% CI: 0.99-1.02) after accounting for province or territory, age group, and sex. In comparison to Ontario, the incidence rate of OHCA patients admitted to the hospital was significantly higher in British Columbia (IRR: 1.15, 95% CI: 1.07-1.24), Manitoba (IRR: 1.13, 95% CI: 1.02-1.25), and Nova Scotia (IRR: 1.13, 95% CI: 1.01-1.26), but it was significantly lower in New Brunswick (IRR: 0.82, 95% CI: 0.71-0.93). The incidence rate of OHCA patients admitted to the hospital increased as patient age increased (P-value for trend < 0.0001). Compared to female patients, male patients had a higher incidence rate (IRR: 2.15, 95% CI: 2.04-2.27).

Survival outcomes

Over the 5-year period, the proportion of OHCA patients who were admitted to the hospital and survived to discharge was highest in Prince Edward Island (57%) and lowest in Ontario (38%), with a national average of 43%. No significant trend in the proportion of OHCA patients who were admitted to the hospital and survived to discharge was observed from 2013 (43%) to 2017 (42%; $P = 0.8640$) in Canada. The proportions of OHCA patients who were admitted to the hospital and survived to discharge, by year and province, are displayed in Figure 2 (see Supplemental Table S9 for exact counts and percentages). No significant trends in the proportion of OHCA patients who were admitted to the hospital and survived to discharge were observed during the period 2013-2017 for any individual province, although the territories demonstrated a significant increasing trend ($P = 0.0341$; data not reported due to small cell suppression). The proportion of OHCA patients who were admitted to the hospital and survived to discharge, by year, stratified by age group and sex, are displayed in Figure 3 (see Supplemental Table S9 for exact counts and percentages). In general, the proportion of OHCA patients who were admitted to the hospital and survived to discharge decreased with increasing patient age. A greater proportion of male OHCA patients admitted to the hospital survived to discharge, compared to the proportion of female OHCA patients admitted, across all years (5-year period: 47% vs 36%).

Discussion

This population-based study was the first to comprehensively evaluate the incidence and outcomes of OHCA patients

Table 1. Demographic and clinical characteristics of out-of-hospital cardiac arrest (OHCA) patients admitted to the hospital (aged 2-85 years)

Characteristic	2013–2017 (n = 10,492)	2013 (n = 1988)	2014 (n = 2051)	2015 (n = 2097)	2016 (n = 2152)	2017 (n = 2204)	*P* for trend
Age, y	66 (55, 75)	66 (55, 75)	66 (55, 75)	66 (55, 75)	65 (55, 74)	65 (54, 75)	0.0613
Male sex	6953 (66)	1334 (67)	1344 (66)	1377 (66)	1434 (67)	1464 (66)	0.9625
Hospital length-of-stay, d	5 (1,13)	5 (1,13)	5 (1,13)	5 (1,13)	5 (1,13)	4 (1, 12)	0.1255
Patient location of residence							0.0411
Urban	9191 (89)	1722 (88)	1786 (88)	1851 (89)	1899 (90)	1933 (90)	
Rural	1115 (11)	226 (12)	239 (12)	220 (11)	206 (9.8)	224 (10)	
Missing	186	40	26	26	47	47	
Hospital type							
Teaching	4589 (44)	834 (42)	911 (44)	878 (42)	954 (44)	1012 (46)	0.0209
Large community	4159 (40)	825 (41)	760 (37)	868 (41)	886 (41)	820 (37)	0.0674
Medium community	1525 (15)	284 (14)	330 (16)	306 (15)	286 (13)	319 (14)	0.3129
Small community	219 (2.1)	45 (2.3)	50 (2.4)	45 (2.1)	26 (1.2)	53 (2.4)	0.3553
Province or territory							
Alberta	1299 (12)	244 (12)	269 (13)	251 (12)	276 (13)	259 (12)	0.5431
British Columbia	2149 (20)	423 (21)	386 (19)	435 (21)	441 (20)	464 (21)	0.6337
Manitoba	505 (4.8)	91 (4.6)	100 (4.9)	95 (4.5)	99 (4.6)	120 (5.4)	0.3116
New Brunswick	262 (2.5)	46 (2.3)	45 (2.2)	55 (2.6)	64 (3.0)	52 (2.4)	0.4334
Newfoundland and Labrador	228 (2.2)	51 (2.6)	32 (1.6)	56 (2.7)	42 (2.0)	47 (2.1)	0.6497
Nova Scotia	445 (4.2)	84 (4.2)	103 (5.0)	79 (3.8)	91 (4.2)	88 (4.0)	0.3616
Ontario	5153 (49)	974 (49)	1010 (49)	1035 (49)	1049 (49)	1085 (49)	0.9914
Prince Edward Island	51 (0.5)	8 (0.4)	11 (0.5)	9 (0.4)	10-15	10-15	0.5910
Saskatchewan	364 (3.5)	61 (3.1)	86 (4.2)	71 (3.4)	74 (3.4)	72 (3.3)	0.7485
Territories	36 (0.3)	6 (0.3)	9 (0.4)	11 (0.5)	≤ 5	≤ 5	0.3549
Past medical history with 5 years prior to index event							
Any comorbidity	4895 (47)	940 (47)	982 (48)	993 (47)	987 (56)	993 (45)	0.0565
Atrial fibrillation	662 (6.3)	176 (8.9)	170 (8.3)	128 (6.1)	96 (4.5)	92 (4.2)	< 0.0001
Cancer	790 (7.5)	148 (7.4)	157 (7.7)	168 (8.0)	150 (7.0)	167 (7.6)	0.8110
Chronic obstructive pulmonary disease	1199 (11)	255 (13)	234 (11)	240 (11)	240 (11)	230 (10)	0.0227
Coronary artery disease	1667 (16)	346 (17)	348 (17)	355 (17)	307 (14)	311 (14)	0.0002
Diabetes	2230 (21)	416 (21)	449 (22)	426 (20)	468 (22)	471 (21)	0.7907
Dyslipidemia	477 (4.5)	109 (5.5)	84 (4.1)	101 (4.8)	101 (4.7)	82 (3.7)	0.0422
Heart failure	1627 (16)	327 (16)	334 (16)	319 (15)	324 (15)	323 (15)	0.0547
Hypertension	2903 (28)	528 (27)	604 (29)	608 (29)	585 (27)	578 (26)	0.3045
STEMI	232 (2.2)	48 (2.4)	50 (2.4)	47 (2.2)	53 (2.5)	34 (1.5)	0.0839
Other MI	835 (8.0)	182 (9.2)	177 (8.6)	165 (7.9)	160 (7.4)	151 (6.9)	0.0019
Peripheral artery disease	61 (0.6)	11 (0.6)	14 (0.7)	8 (0.4)	13 (0.6)	15 (0.7)	0.7229
Renal failure	1433 (14)	252 (13)	277 (14)	292 (14)	300 (14)	312 (14)	0.1578
Cardiovascular procedures within 5 years prior to index event							
Any cardiovascular procedure	1516 (14)	287 (14)	325 (16)	320 (15)	291 (14)	293 (13)	0.0517
Angiography	1275 (12)	244 (12)	280 (14)	265 (13)	237 (11)	249 (11)	0.0387
CABG	216 (2.1)	47 (2.4)	41 (2.0)	37 (1.8)	41 (1.9)	50 (2.3)	0.8088
ICD	162 (1.5)	34 (1.7)	43 (2.1)	25 (1.2)	30 (1.4)	30 (1.4)	0.1014
Pacemaker	199 (1.9)	34 (1.7)	42 (2.0)	48 (2.3)	43 (2.0)	32 (1.5)	0.5066
PCI	482 (4.6)	96 (4.8)	102 (5.0)	106 (5.1)	87 (4.0)	91 (4.1)	0.1024
Any hospitalization within 5 years prior to index event							
Any hospitalization	6408 (61)	1218 (61)	1252 (61)	1286 (61)	1315 (61)	1337 (61)	0.7281
Any cardiovascular hospitalization	4393 (42)	860 (43)	899 (44)	893 (43)	883 (41)	858 (39)	0.0007

Values are n (%), or median (interquartile range), unless otherwise indicated. Small cells (≤ 5) were suppressed for privacy and confidentiality purposes.

CABG, coronary artery bypass graft; ICD, implantable cardioverter-defibrillator; MI, myocardial infarction; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation MI.

admitted to the hospital across 9 provinces and all 3 territories in Canada, using health administrative datasets. Over the study period, the annual age- and sex-standardized incidence of OHCA patients admitted to the hospital remained stable. Although significant decreasing trends in the prevalence of various cardiovascular comorbidities were observed among admitted OHCA patients during the period 2013-2017, the proportion of patients who survived to hospital discharge did not change. Incidence measures and outcomes varied substantially across Canadian provinces and territories.

Based on an estimated incidence of 55 per 100,000 population for adult, nontraumatic, EMS-treated OHCA patients,[6] the findings from our study imply that approximately 1 in 7 OHCA patients survive to hospital admission in

Table 2. Crude and standardized (Std) incidence of out-of-hospital cardiac arrest (OHCA) patients admitted to the hospital (per 100,000 population) by year, and province or territory

Region	Overall (2013–2017)		2013		2014		2015		2016		2017	
	Crude	Std (95% CI)	Crude	Std (95% CI)	Crude	Std (95% CI)	Crude	Std (95% CI)	Crude	Std (95% CI)	Crude	Std (95% CI)
Canada*	7.9	8.3 (8.1–8.4)	7.7	8.2 (7.9–8.6)	7.8	8.3 (7.9–8.7)	7.9	8.3 (7.9–8.7)	8.0	8.3 (8.0–8.7)	8.1	8.3 (8.0–8.7)
Alberta	6.5	8.0 (7.5–8.4)	6.4	8.0 (7.0–9.1)	6.9	8.6 (7.6–9.7)	6.3	7.8 (6.9–8.9)	6.8	8.1 (7.2–9.1)	6.4	7.4 (6.5–8.4)
British Columbia	9.3	9.2 (8.8–9.6)	9.5	9.5 (8.7–10.5)	8.5	8.5 (7.7–9.4)	9.5	9.3 (8.4–10.2)	9.4	9.1 (8.3–10.0)	9.8	9.4 (8.6–10.3)
Manitoba	8.2	9.0 (8.2–9.8)	7.5	8.4 (6.7–10.3)	8.2	9.1 (7.4–11.1)	7.7	8.5 (6.9–10.4)	7.9	8.7 (7.1–10.6)	9.4	10.3 (8.5–12.3)
New Brunswick	7.2	6.5 (5.7–7.3)	6.3	6.0 (4.4–8.0)	6.2	5.7 (4.1–7.6)	7.5	6.8 (5.2–8.9)	8.7	7.8 (6.0–10.0)	7.0	6.2 (4.6–8.2)
Newfoundland and Labrador	8.9	8.2 (7.2–9.4)	10.0	9.6 (7.1–12.6)	6.3	5.8 (4.0–8.2)	10.9	10.2 (7.7–13.3)	8.2	7.5 (5.4–10.2)	9.2	8.0 (5.9–10.7)
Nova Scotia	9.8	9.0 (8.2–9.9)	9.3	8.8 (7.0–10.9)	11.4	10.6 (8.7–12.9)	8.7	8.0 (6.3–10.0)	10.0	9.0 (7.2–11.1)	9.6	8.6 (6.9–10.6)
Ontario	7.8	8.1 (7.9–8.3)	7.5	8.0 (7.5–8.6)	7.7	8.1 (7.6–8.6)	7.9	8.1 (7.6–8.6)	7.9	8.1 (7.6–8.6)	8.0	8.1 (7.7–8.6)
Prince Edward Island	7.3	6.8 (5.0–8.9)	5.8	5.6 (2.4–11.1)	7.9	7.6 (3.8–13.6)	6.5	6.0 (2.7–11.4)	7.8	6.9 (3.5–12.6)	8.3	7.5 (3.8–13.1)
Saskatchewan	6.8	7.5 (6.8–8.3)	5.8	6.4 (4.9–8.2)	8.1	9.1 (7.2–11.2)	6.6	7.4 (5.8–9.3)	6.8	7.5 (5.9–9.5)	6.6	7.2 (5.6–9.0)
Territories	6.3	8.3 (5.6–11.8)	5.4	6.2 (2.1–14.9)	8.0	9.9 (4.1–20.1)	9.7	14.4 (6.7–26.7)	4.3	3.8 (1.2–10.3)	4.3	6.7 (2.1–15.7)

Denominators for each provincial or territorial population (aged 2-85 years) are based on July 1 population estimates (2013–2017). Standardized values were determined by age and sex, according to the 2016 Canadian population (aged 2–85 years).

CI, confidence interval; OHCA, out-of-hospital cardiac arrest; Std: standardized.

* Denominators for the Canada row used the Canadian population, excluding Quebec (aged 2-85 years), based on July 1 population estimates (2013-2017).

Table 3. Negative binomial regression model output

Characteristic	IRR	95% CI	*P*
Year (per 1-year)	1.01	0.99–1.02	0.5709
Province or territory			
Ontario	Ref.		
Alberta	1.00	0.92–1.08	0.9899
British Columbia	1.15	1.07–1.24	0.0001
Manitoba	1.13	1.02–1.25	0.0243
New Brunswick	0.82	0.71–0.93	0.0030
Newfoundland and Labrador	1.02	0.88–1.18	0.7861
Nova Scotia	1.13	1.01–1.26	0.0350
Prince Edward Island	0.85	0.64–1.13	0.2628
Saskatchewan	0.94	0.83–1.05	0.2712
Territories	1.18	0.85–1.64	0.3291
Age group, y			
2–18	Ref.		< 0.0001
19–35	5.85	4.55–7.52	< 0.0001
36–45	11.9	9.24–15.2	< 0.0001
46–55	27.9	21.9–35.5	< 0.0001
56–65	48.9	38.5–62.1	< 0.0001
66–75	89.2	70.2–113.2	< 0.0001
76–85	144.0	113.4–183.0	< 0.0001
P for trend*	<0.0001		
Sex			
Female	Ref.		
Male	2.15	2.04–2.27	< 0.0001

CI, confidence interval; IRR, incidence rate ratio; Ref., referent.

* Computed by treating age group as a continuous predictor in the model.

Canada. As the DAD has been shown to undercount OHCA hospital admissions by approximately 30%, due to provider- and hospital-specific ICD-10 coding preferences (Visanji et al., abstract, October 8, 2024), the true rate of survival of OHCA patients to hospital admission in Canada is likely between 1 in 5 (20%) and 1 in 4 (25%). These estimates are of similar magnitude to those found in smaller studies conducted within individual Canadian provinces.[19,43,44]

The conclusions of this study should be interpreted in the context of the study population, which included only those OHCA patients who survived to hospital admission. As a result, the reported incidences and survival outcomes are influenced by prehospital and ED variables, such as bystander interventions, EMS response times, and the timeliness of provision of advanced resuscitative care, which we could not assess in this study. Additionally, survival after hospital admission depends on the extent of cardiac and cerebral damage incurred prior to admission, as well as the quality of in-hospital care, which is evolving with updated Canadian guidelines.[22] This complexity necessitates a cautious interpretation of our findings. Nonetheless, our study provides insights into the underlying comorbidities of OHCA patients, the quality of in-hospital care they receive, and temporal trends in population-relevant measures, such as incidence of hospital admission and survival to hospital discharge.

Two previous studies evaluated the incidence and outcomes of OHCA patients admitted to the hospital in Canada. Redpath et al. conducted a retrospective cohort study of 13,263 OHCA patients who survived to hospital admission in 8 Canadian provinces during the period 1994-2004, noting a decreasing trend in incidence, yet no significant trend in the rate of survival to hospital discharge (38% over the study period).[20] Notably, this study had 2 key limitations. First, data from Prince Edward Island, British Columbia, and the

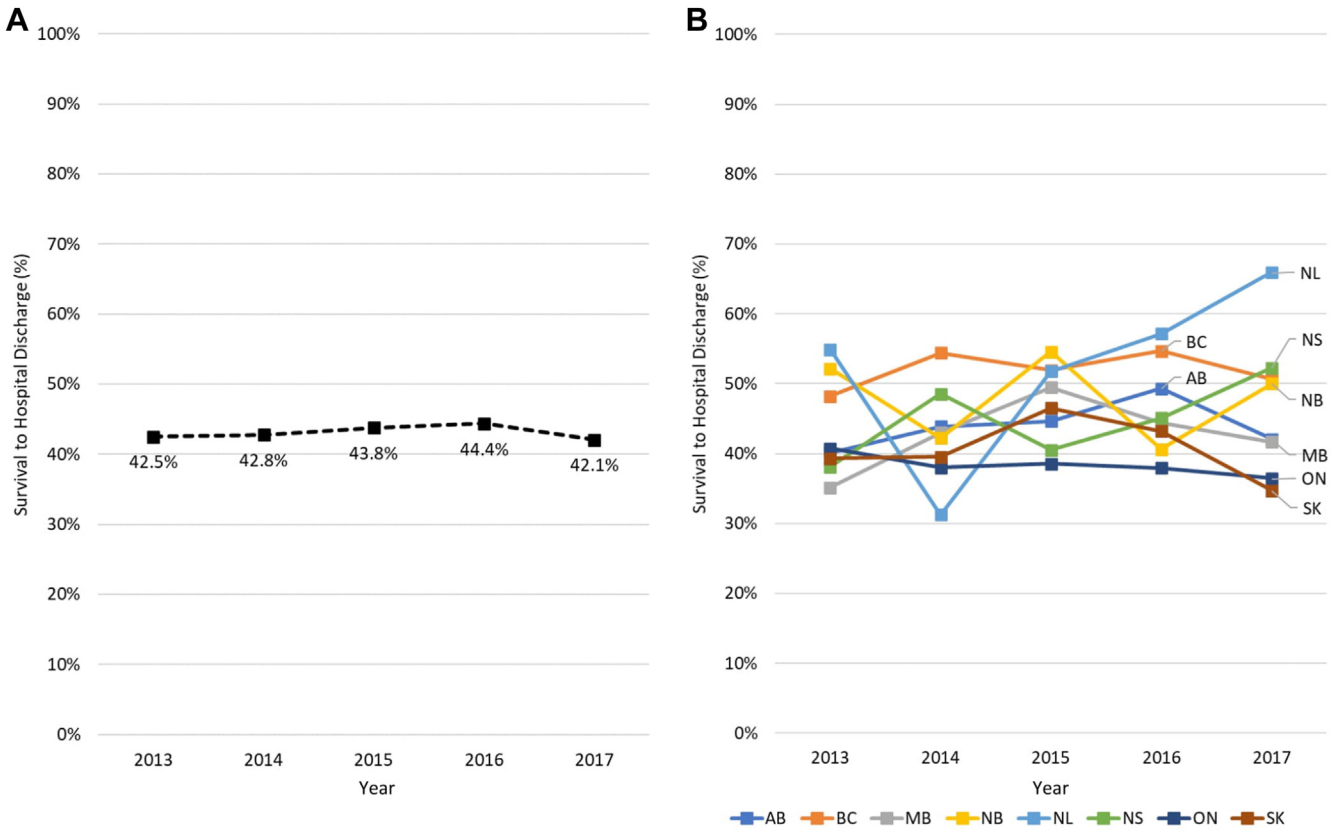

Figure 2. Survival to hospital discharge, by year, and stratified by province among out-of-hospital cardiac arrest (OHCA) patients admitted to the hospital in Canada (excluding Quebec) during the period 2013-2017. (**A**) Canada (excluding Quebec). (**B**) stratified by province (data from Prince Edward Island and the Territories were excluded due to small cell restrictions). AB, Alberta; BC, British Columbia; MB, Manitoba; NB, New Brunswick; NL, Newfoundland and Labrador; NS, Nova Scotia; OHCA, out-of-hospital cardiac arrest; ON, Ontario; SK, Saskatchewan.

Canadian territories were not included in the study cohort, thus limiting the generalizability of the findings to Canada as a country. Second, ICD-10 codes for ill-defined and unknown causes of mortality (R96.0, R96.1, R98, and R99) were not used to identify OHCA cases; as a result, the reported incidence may have been underestimated, and other results may have been impacted, due to the potential for selection bias. In another retrospective cohort study of 34,291 adult OHCA patients who were transported alive to any Ontario-based acute-care hospital during the period 2002-2012, Wong et al. found no significant changes in the age- and sex-standardized incidence of OHCA over the study observation window.[21] However, 30-day and 1-year survival rates did improve over the 10-year period. Important to note is that this study was conducted within only a single Canadian province and did not include pediatric OHCA cases. The substantial difference in the total number of included cardiac arrests—~3500 per year for Ontario, based on data from Wong et al. vs ~2100 per year for Canada (excluding Quebec) in our study—may be due to the distinct populations analyzed (ie, OHCA patients transported alive to the ED vs OHCA patients admitted to the hospital).[21] In comparison to these 2 studies, our analysis used a comprehensive and validated list of ICD-10 codes to identify OHCA cases, and it included data from all Canadian provinces and territories (excluding Quebec). Additionally, our OHCA identification algorithm used diagnosis-type codes in the DAD, to exclude any *probable* in-hospital cardiac arrests, which were not utilized in prior studies, to our knowledge.[20,21] In the absence of a formal nationwide registry for OHCA cases, our investigation provides updated surveillance data that can be used to guide the development of future public health and clinical interventions for OHCA patients in Canada.

The annual incidence and proportion of patients who survived to hospital discharge remained steady throughout the 5-year study period, a finding consistent with earlier data from Ontario (for the period 2002-2012).[21] Similar findings also have been observed among all EMS-assessed OHCA patients in Canada, based on data from the CanROC registry.[6] Regional variations in both the incidence and outcomes of OHCA patients admitted to the hospital were evident across Canada, echoing results from an earlier study.[20] Canada's smallest province, in terms of population and land area—Prince Edward Island—had the greatest proportion of patients who survived to hospital discharge after OHCA, despite a high comorbidity burden among patients residing in this province (55% were diagnosed with $\geq$ 1 comorbidity, and 67% were hospitalized in the 5 years prior to their index event). In comparison, the Canadian province with the largest population—Ontario—had the poorest survival outcomes, with only 38% of OHCA patients surviving to hospital discharge over the 5-year period. We speculate that these

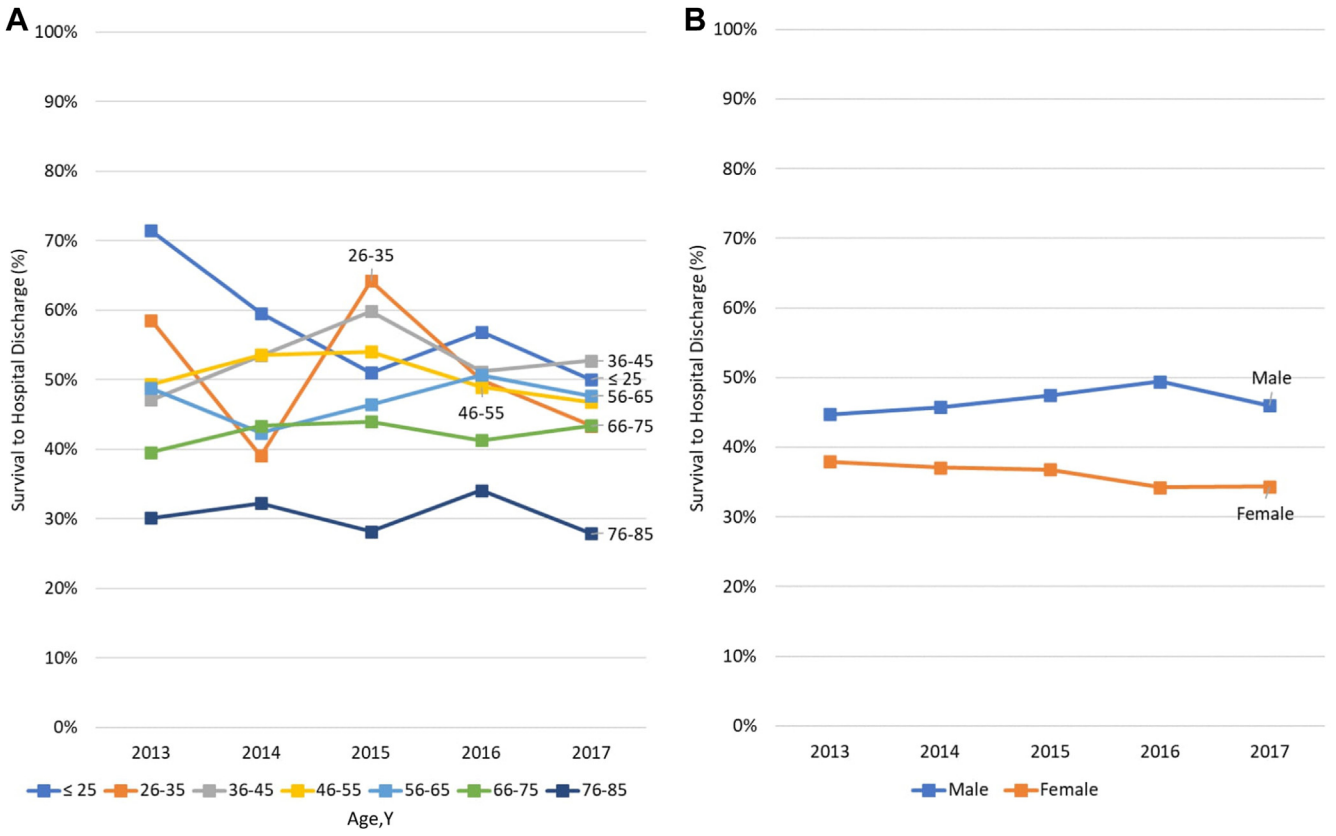

Figure 3. Survival to hospital discharge by year, stratified by age group and sex, among out-of-hospital cardiac arrest patients admitted to the hospital in Canada (excluding Quebec) during the period 2013-2017. (**A**) Stratified by age group (data from the age group of 2–18 years were excluded due to small cell restrictions). (**B**) Stratified by sex.

findings may, in part, be due to the following: the quality of in-hospital care received; regional differences in cardiac arrest characteristics; patient characteristics (eg, prior medical history); prehospital care, such as bystander cardiopulmonary resuscitation (CPR) and automated external defibrillator use; advanced cardiac life-support interventions; and post–cardiac arrest care. These differences could be attributable to the heterogeneity of population densities across Canadian provinces and territories,[28] which may underpin dissimilarities in terms of the social cohesion of communities and the distances between EMS centres or publicly available automated external defibrillators. However, a point that should be highlighted is that we were unable to distinguish between the effects of environmental factors and prehospital-care factors from the effects of in-hospital care on outcomes after OHCA in our cohort. Furthermore, another important point to consider is that the survival rates calculated in our study are specific to OHCA patients who were admitted to acute-care hospitals. A high proportion of patients suffering from cardiac arrest are pronounced dead, either in the field or in the ED, and are never admitted to the hospital. Therefore, lower survival rates in some regions may, paradoxically, reflect effective prehospital care, especially if patients with poor prognoses are admitted alive. Conversely, higher survival rates may indicate less-prompt or less-effective prehospital care, resulting in only those OHCA patients who have favourable prognoses being admitted. Although the outcomes reported in our study represent an integrated measure that is influenced by an individual's health status, the contextual environment, and care-related factors, this measure still can be used as an indirect indicator of the quality of in-hospital care received by patients after OHCA. To comprehensively elucidate regional differences in outcomes, studies designed to disentangle the unique effects of these variables on OHCA survivorship may be an avenue for future work. For example, future studies that are conducted in populations with coordinated EMS and hospital data may wish to perform geospatial analyses to better understand geographic differences in the incidence and outcomes of OHCA patients admitted to the hospital. The receiving-hospital type (ie, hospital size, academic status, etc.), and other geographic differences in systems of care, may have influenced admission rates, care processes, and patient outcomes after OHCA. Future investigations should take such variability into account.

Disparities in the outcomes of OHCA patients admitted to the hospital across provinces and territories emphasize the need for region-specific strategies that are designed to optimize in-hospital care and post–cardiac arrest recovery. These strategies should be tailored to consider the typical demographic and clinical characteristics (eg, comorbidities, prior procedures) of the underlying patient population. An interesting finding in our study is that the prevalence of various comorbidities and previous cardiovascular hospitalizations in our patient cohort displayed decreasing temporal trends during

the period 2013-2017, without significant changes occurring in patient demographic characteristics over time. A similar finding was observed among OHCA patients who were admitted to the hospital in Ontario during the period 2002-2012.[21] This observation may indicate population-level improvements in preventative care and outpatient management, or a shift in the pattern of prodromal symptoms that precede OHCA (ie, OHCA as the first manifestation of underlying disease). However, further research is needed to confirm these hypotheses. Although temporal trends in the accuracy of medical coding and abstracting may offer an alternative explanation, this possibility is unlikely, given the consistent use of the ICD-10-Canada/Canadian Classification of Health Interventions (CA/CCI) coding system in all Canadian provinces and territories since 2006.[45] Future etiologic studies should aim to describe the complex associations of both cardiovascular risk factors and established comorbidities with survival outcomes after OHCA, particularly among those patients who survived to hospital admission.

Strengths and limitations

A major strength of this study was the use of a large and nationally representative cohort of OHCA patients who were admitted to a hospital, thus allowing for generalizability to the Canadian population aged 2-85 years. As the record-level nonresponse rate (0.048% for the 2016-2017 fiscal year), and the rate of missingness for clinical variables (< 0.01% for the 2016-2017 fiscal year) in the DAD is negligible, the study cohort accurately represents the target population (OHCA patients admitted to the hospital).[46] Other strengths include the use of a previously validated OHCA ascertainment algorithm and high-quality administrative data to derive all study variables, thus reducing the potential for misclassification.[27,47,48]

The findings of this study should be interpreted taking into account the following limitations. First, the target population of this study included only those OHCA patients who were admitted to an acute-care hospital. Patients who were transported to an ED, but did not survive to hospital admission, were not included in the target population, owing to data-coverage limitations of the National Ambulatory Care Reporting System (NACRS), the use of which is mandated in only 4 provinces and territories.[49] Second, trends in the incidence of OHCA patients admitted to the hospital in the province of Quebec, and their outcomes, could not be analyzed, owing to authorization restrictions. Third, the small number of observed OHCA patients (5-12) in certain annual strata for Prince Edward Island and the territories may have resulted in unstable estimates; thus, the standardized incidence measures for these regions should be interpreted with caution. Fourth, although we recognize the importance of considering the underlying pathology of OHCA, and geographic differences in healthcare access, the lack of linked records and the unavailability of exact cardiac-arrest addresses limited our ability to analyze prehospital characteristics, as well as time- and distance-related metrics. Future research should aim to address these gaps. Finally, the DAD does not include clinical information on the neurologic and functional status of patients upon hospital discharge. As a result, this analysis was unable to evaluate temporal trends in the functional recovery of OHCA patients admitted to the hospital.

Conclusions

During the period 2013-2017, the age- and sex-standardized incidence of OHCA patients admitted to the hospital remained consistent in Canada, and no notable shift occurred in the proportion of patients surviving to hospital discharge. Across Canada, regional differences in both the incidence and outcomes of OHCA patients admitted to the hospital were observed. Future research and tailored policies should be considered to improve survival rates and the quality of care received by patients after they experience an OHCA within national geographic jurisdictions.

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Ethics Statement

Data used in this study were collected under a waiver of consent from the Canadian Institute for Health Information (CIHI). This study was approved by the Unity Health Toronto Research Ethics Board (REB #18-146).

Patient Consent

The authors confirm that patient consent does not apply to the research reported in this article. The CIHI is a prescribed entity under Section 45 of the Ontario Personal Health Information Protection Act (PHIPA). This designation authorizes the CIHI to collect personal health information for analyzing or compiling data that will be used to manage, evaluate, and monitor how resources are allocated, aiding in the planning and improvement of health systems across all or parts of Canada.[50] Our secondary data analysis of the DAD did not require individual patient consent, as all data were deidentified and no personal health information was disclosed.

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Disclosures

The authors have no conflicts of interest to disclose.

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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.2024.09.015.