Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Temporal trends in sudden cardiac death in Ontario, Canada

Mony Shuvy[a,b], *Feng Qiu*[c], *Geoffrey Lau*[c], *Maria Koh*[c], *Paul Dorian*[d], *Guillaume Geri*[c,e], *Steve Lin*[f], *Dennis T. Ko*[a,c,*]

[a] Schulich Heart Centre, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario, Canada
[b] Heart Institute, Hadassah-Hebrew University Medical Centre, Jerusalem, Israel
[c] Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada
[d] Division of Cardiology, Department of Medicine, St Michael's Hospital, Toronto, Ontario, Canada
[e] Ambroise Paré Hospital– Greater Paris University Hospitals, France
[f] Department of Emergency Medicine, St. Michael's Hospital, Toronto, Ontario, Canada

Abstract

Aims: Although the prevention and treatment of cardiovascular conditions have significantly improved over the past decade, whether they have reduced the incidence of sudden cardiac death (SCD) is not known. We sought to evaluate the temporal trends of SCD in a large unselected population.

Methods: We conducted a population-based cohort study using multiple linked longitudinal data in Ontario Canada. We included patients aged 35–74 years who had SCD from April 1st 2003 to March 31st 2014. SCD was defined as those who died of cardiac causes outside of the hospital or the emergency department, and had no recent hospitalization, no serious illness, and who were not residing in long-term care facilities.

Results: We identified 36,334 patients who fulfilled criteria for SCD. The overall age and sex-standardized rate of SCD declined from 57.9/100,000 in fiscal year 2003 to 42.4/100,000 in 2013. Men and women had similar declining trends in SCD incidence. Larger reductions were seen among the older age groups. Patients who had prior heart failure experienced the largest decline in SCD incidence from 829/100,000 to 533/100,000 from 2003 to 2013. Patients who had prior myocardial infarction also had significant reduction from 484/100,000 to 381/100,000. In contrast, individuals with cardiac risk factors without disease had much smaller declines in SCD incidence.

Conclusions: Although significant progress to reduce SCD among patients with cardiac conditions was made in the past decade, additional effort should focus on the prevention of SCD in individuals without heart disease.

Keywords: Temporal trends, Sudden cardiac death

Introduction

Despite substantial improvement in the prevention of cardiac disease andtreatment of patients with established cardiovascular disease over the past decades, sudden cardiac death (SCD) remains one of the most common causes of death in developed countries.[1–3] Some estimates suggest that 4–5 million patients suffer SCD each year worldwide.[4] SCD is classically defined as the cessation of cardiac function leading to unexpected death within an hour of symptom onset.[5] Due to the difficulty in adopting an operational definition that can be easily applied to the general population, little is known regarding the recent epidemiology of SCD.

Population-based studies using modified SCD definitions from the Netherlands and Australia have shown a significant decline in SCD incidence from the 1990s to 2010.[6,7] In contrast, a study from Japan showed that incidence of SCD decreased from 1981 to 1995 but was unchanged from 1996 to 2005.[8] Studies from North America have

* Corresponding author at: Institute for Clinical Evaluative Sciences (ICES), G1-06, 2075 Bayview Ave, Toronto, Ontario, M4N 3M5, Canada.
E-mail address: dennis.ko@ices.on.ca (D.T. Ko).

https://doi.org/10.1016/j.resuscitation.2019.01.010
Received 13 September 2018; Accepted 6 January 2019

focused mainly on patients with out-of-hospital cardiac arrest (OHCA) because data are more readily obtainable by emergency medical services.[9–11] Surprisingly, the incidence of OHCA has not significantly changed in the past 5 years.[12,13] Other countries have also noted a stable incidence of cardiac arrest patients in the population.[3] Whether there is an offsetting effect of improved cardiovascular treatment and increasing epidemic of obesity, diabetes, and hypertension is uncertain.[14–19]

Insight into the recent epidemiology of SCD could provide valuable public health data into gaps in knowledge and enable focus on deriving strategies to prevent these lethal events in the future. Accordingly, the first objective of our study was to evaluate the temporal trends of SCD incidence in a large unselected population. Second, we performed stratified analyses based on demographics, cardiac risk factors, and prior cardiac conditions to gain insight on potential discrepancies in the temporal trends of SCD incidence.

Methods

Design and data sources

We conducted a retrospective cohort study using multiple large longitudinal population-based databases in Ontario, Canada, as previously described.[11,20–22] Linkage of these databases was performed using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences (ICES) to protect patient confidentiality. Demographic information of the Ontario population was identified using the Registered Persons Database, which is a registry of all residents who are eligible for the Ontario Health insurance Plan. Cause of death data was obtained by the Registrar General of Ontario Vital Statistics Database, which collects information on date and location of death, and uses death certificates or coroners' report when available to determine etiologies of death. The Canadian Institute for Health Information (CIHI) Discharge Abstract Database was used to identify comorbidities, and medical and surgical procedures. The Ontario Drug Benefits database was used to obtain medication information for individuals older than 65 years old.

Identification of SCD

Patients who died suddenly of cardiac causes were identified using a previously validated case definition.[23] This algorithm has been extensively used to conduct population-based studies to evaluate SCD associated with medications.[24–28] Additional information of how this method was adopted in this study is shown in the Supplemental Appendix. Our cohort was first restricted to those aged 35–74 years, who died at home or in the emergency department, and did not reside in long-term care facilities because the identification of SCD was much less accurate outside these parameters.[23] We also excluded patients who were admitted to hospital within 30 days before the index date and individuals with a history of serious illness because deaths in these populations are less likely to be sudden. Serious illnesses were defined as prior hospitalization with cancer, HIV infection, moderate to severe liver disease, renal dialysis, organ transplantation, neuromuscular disorder, drug abuse, mental disorder, and stroke with paraplegia in the past 5 years using the CIHI discharge abstract database. Finally, cardiac causes of death were defined using international classification of disease codes, 9th version: 7981, 7982, 7989, 7999, 390-429, and 440-459. This algorithm has been previously validated against clinical review and found to have a positive predictive value of 87%.[23]

Study cohorts

Using the previously described algorithm, we created a cohort that included patients who had SCD in Ontario from April 1, 2003 to March 31, 2014. We also created cohorts of individuals in the general Ontario population of similar age (35–74 years) who are at risk for SCD.

Statistical analysis

The patient cohort was stratified by the Canadian fiscal year (April 1–March 31) of the index event. Temporal changes in the demographics and clinical characteristics of the SCD cohort and the general population were evaluated. Statistical significance was established using the Cochrane–Armitage Trend test for categorical variables and linear regression for continuous variables. We calculated age- and sex-standardized SCD incidence rate from 2003 to 2013 through direct standardization using the annual cohorts of the general population. To gain additional perspective on the potential discrepancy of the temporal trends of SCD incidence, we created three a priori defined subgroups based on clinical characteristics; (a) primary prevention subgroup with hypertension, diabetes or hyperlipidemia but no established cardiovascular disease, (b) myocardial infarction, and (c) heart failure.

Temporal changes in SCD rates were estimated using linear regression methods. Average annual relative percentage change in SCD rates was calculated by linear regression of the log rates. Relative change in SCD rates was calculated by comparing rates in fiscal year 2013–2003 as a reference.

Statistical significance was established with a 2-sided P value of <0.05. All analyses were performed at the Institute of Clinical Evaluative Sciences in Toronto, Canada using SAS 9.1.3 software (SAS Institute Inc., Cary, NC). This study was approved by the research ethics board at Sunnybrook Health Sciences Centre in Toronto, Canada.

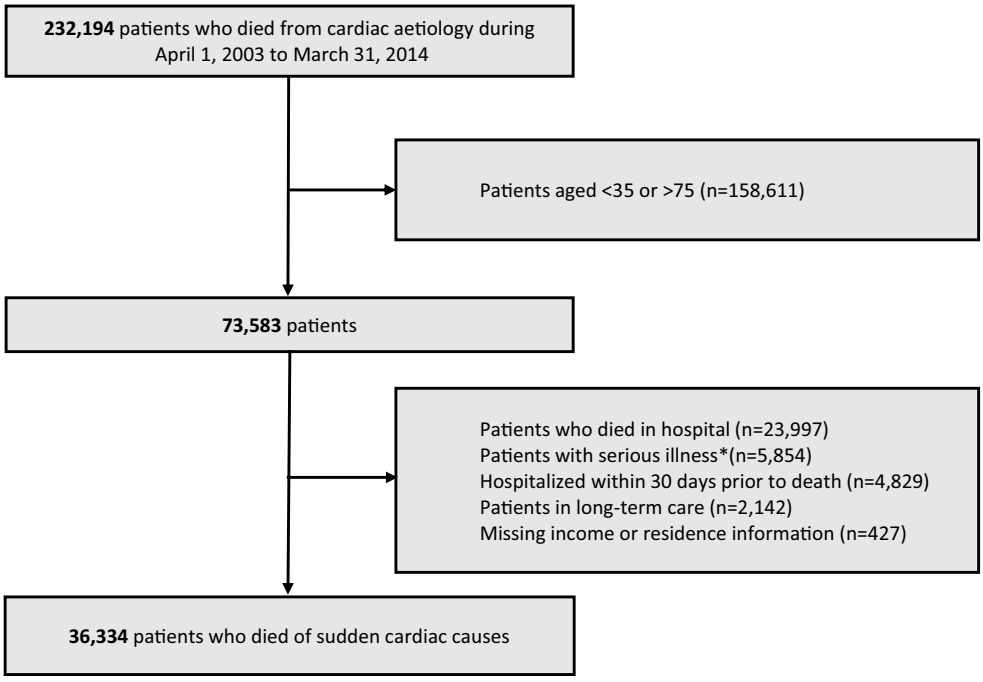
Results

Creation of the SCD cohort

There were 232,194 patients who died of cardiac causes from April 1, 2003 to March 31, 2014 in Ontario, Canada (Fig. 1). We excluded 158,611 patients who were younger than 35 years or older than 75 years, 23,997 patients who died in hospital, 5854 patients who had serious illnesses in the past 5 years, 4829 patients who had recent hospitalization, 2142 patients who resided in long-term care facilities, and 427 patients with missing information. After applying these exclusion criteria, our cohort included 36,334 SCD patients.

Trends in baseline characteristics of SCD patients

Demographic and baseline characteristics of SCD patients stratified by year of the event are shown in Table 1. Overall, the mean age was 61.5 and 75.1% were men. The prevalence of diabetes, hypertension, and hyperlipidemia significantly increased



[a] Please see the supplemental appendix for the definition of serious illness.

Fig. 1 – Creation of the study cohort.
Using the entire Ontario population aged 35-74 years who had dead from April 1, 2003-March 31, 2014, a total of 36,334 patients were classified as died as sudden cardiac causes.

over the study period ($P < 0.001$). In contrast, rates of myocardial infarction decreased substantially from 11.5% in 2003 to 8.4% in 2013. Similarly, rates of heart failure among SCD patients also decreased from 21.1% to 17.5% during the study period. Use of percutaneous coronary interventions and implantable cardioverter-defibrillators increased from 1.9% to 4.3%, and 0.4% to 1.5%, respectively over the study period (all $P < 0.001$). The use of medications among patients over 65 years where medication information was available also increased: renal-angiotensin system blockers increased by 4%, beta-blockers by 1.1%, and statins by 12.8% (all $P < 0.001$).

Trends in baseline characteristics of the general population

eTable 1 shows the demographics and characteristic of the entire Ontario population aged 35–74 years. There was significantly population growth during the study period from 6.3 million individuals in 2003 to 7.2 million in 2013. Population rates of hypertension and diabetes increased, while rates of hyperlipidemia decreased during the study period. Rates of cardiac events, medical comorbidities, and cardiac procedures were low in the population. While rates of myocardial infarction appeared to have decreased, rates of heart failure were not substantially different from 2003 to 2013.

Temporal trends of SCD incidence by age and sex

Between the years 2003 and 2013, the age and sex-standardized SCD rate per 100,000 individuals declined from 57.9 to 42.4 (Table 2). This was equivalent to a relative reduction of 27% and an annual decline of 1.6 events/100,000 during the study period. SCD incidence was more than three times higher in men (64.1/100,000) as compared to women (21.0/100,000) in 2013. Over the study period, both groups had similar declines in the SCD incidence (Table 2 and eFig. 1). SCD incidence also varied substantially by age, the incidence was more than 10 times higher among the oldest age group (70–74 years) compared with the youngest (35–49 years). The largest decline in SCD incidence was seen in the oldest age group, with a 37% relative reduction and 7.8 events/100,000 annual decline in SCD from 2003 to 2013 (Table 2, and eFig. 2). For those aged 35–49 years, only a 15% relative reduction and an absolute decline of 0.3/100,000 was seen (Table 2).

Temporal trends of SCD incidence by cardiac conditions

In 2003, patients with prior heart failure had the highest incidence of SCD, at 829.0/100,000 followed by myocardial infarction patients (484.2/ 100,000). A substantial decrease of SCD was found in these secondary prevention cohorts: 36% relative reduction for CHF, and 21% for MI comparing 2003–2013 (Table 3). The annual reduction in SCD incidence in these patients was large at 30.7/100,000 prior heart failure and 11.4/100,000 for prior myocardial infarction (Fig. 2).

In patients with cardiac risk factors but no heart disease, the incidence of SCD was 64.2/100,000 during the study cohort, almost three times higher compared with those without any cardiac risk factors at 22.4/100,000. A small decrease in the SCD incidence over time was observed in the high-risk primary prevention cohort: from 74 to 64 deaths per 100,000 accounting for a 14% relative reduction, an absolute yearly decline of 1.3/100,000 (Table 3,Fig. 2).

Table 1 – Trend of baselinecharacteristics in cardiac sudden death patients from April 1 2003 to March 31, 2014.

	Overall	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	P value for trend
Number of patients	36,334	3578	3493	3236	3294	3332	3289	3179	3258	3107	3208	3360	
Demographics, %													
Age, Mean ± SD	61.5 ± 9.6	61.9 ± 9.9	62.0 ± 9.8	61.4 ± 9.9	61.4 ± 9.8	61.2 ± 9.7	61.2 ± 9.6	61.3 ± 9.5	61.1 ± 9.5	61.5 ± 9.3	61.8 ± 9.0	61.6 ± 9.2	0.127
Men	75.1	75.6	75.2	74.9	74.8	75.7	76.3	73.6	75.6	74.6	74.5	74.9	0.350
Rural	17	17.7	17.9	17.2	17.2	16.3	16.4	17.3	16.9	16.4	16.5	16.6	0.052
Income quintile													
1	27.9	26.6	26.7	27.9	27.1	27.5	29.2	28.6	28.6	28.8	26.8	29.6	0.005
2	22	22.4	22.9	22.2	22.2	22.7	21	22.1	20.1	21.9	22.7	21.7	0.158
3	18.1	19.1	19	17.8	18.7	16.6	17.7	17.9	19.5	17.5	18.5	17.1	0.147
4	16.9	16.7	16.2	17.1	16.8	17.4	16.6	16.5	17	17.2	17.8	16.4	0.452
5	15.1	15.3	15.2	15	15.2	15.8	15.5	14.9	14.8	14.5	14.2	15.2	0.269
Cardiac risk factors, %													
Hyperlipidemia	27.1	23	24.6	25.6	26.3	26.5	27.3	28.2	29.3	28.5	29.7	30.1	<0.001
Hypertension	56.4	53.1	55.3	54	56.4	55.9	55.3	57.2	55.2	57.7	59	61.2	<0.001
Diabetes	28.1	24.3	25.1	24.1	27	27.1	27.5	29.9	28.5	30.8	32.4	33.8	<0.001
Prior cardiovascular conditions, %													
Myocardial infarction	9	11.5	10.8	10.4	9	8.3	9	7.3	8.2	7.8	8.3	8.4	<0.001
Congestive heart failure	19	21.1	21.1	20.1	19.9	18.4	19.2	17.8	17	18.1	18.4	17.5	<0.001
Atrial fibrillation	9.6	9.6	10.6	9.9	9.5	9.9	8.8	8.8	9.3	9.5	9.5	9.9	0.265
Ventricular arrhythmias	1.4	1.8	2	1.3	1.5	1.2	1.3	1	0.9	1.1	1.5	1.4	0.002
Cerebrovascular disease	2.5	1.2	2.1	2.2	2.9	2.9	2.9	2.5	2.4	2.5	2.6	3.1	<0.001
Peripheral vascular disease	4.1	4.5	4.7	3.9	4.5	4.7	3.6	3.6	3.8	3.4	4	4.3	0.041
Prior medical comorbidities, %													
Renal disease	2.8	3	3.1	3.2	3.4	2.7	2.9	2.5	2.6	2.6	2.5	2.4	0.003
Peptic ulcer disease	1.3	1.4	1.3	1.5	0.9	0.9	1.1	1.1	1.6	1.5	1.5	1.4	0.172
Anemia or blood disease	5.2	5.9	5.3	5.7	4.6	5.4	4.7	4.7	4.9	5	5	6	0.483
Chronic lung disease	7.5	9.5	8.2	7.4	7.9	7.5	6.9	7	6.7	6.9	7.4	7.4	<0.001
Charlson score, Mean ± SD	0.7 ± 1.3	0.7 ± 1.3	0.7 ± 1.3	0.6 ± 1.3	0.6 ± 1.3	0.6 ± 1.3	0.7 ± 1.3	0.6 ± 1.3	0.6 ± 1.3	0.7 ± 1.3	0.7 ± 1.4	0.7 ± 1.4	0.009
Cardiac assessment or procedures in the past 5 years, %													
Cardiac catheterization	11.4	10.9	11	10.8	10.7	11.8	12	11.1	11.7	11	12.4	12.4	0.009
Percutaneous coronary intervention	3.3	1.9	2.4	2.8	3.3	3.5	3.9	3.6	3.7	3	4.4	4.3	<0.001
Coronary artery bypass surgery	1.7	1.6	2	2.2	1.5	2	1.5	1.8	1.7	1.3	1.6	1.8	0.249
Implantable cardioverter-defibrillator	0.9	0.4	0.8	0.4	0.7	0.5	0.9	0.9	1.1	1.5	1.2	1.5	<0.001
Permanent pacemaker	1.1	0.8	1	1.4	0.8	1	1.3	0.9	1.2	0.9	1.4	1.3	0.071
Assessment of ischemia	24	24.7	25	25.2	22.7	23.7	22.5	23.2	24.1	24.5	24.4	24	0.425
Assessment of ventricular function	36	32.1	32.1	32.9	33.1	36.3	36.1	36.7	38.5	38.9	40.4	39.8	<0.001

Abbreviations: SD, standard deviation.

Table 2 – Adjusted rates for sudden cardiac death in men and women aged 35-74 years, Ontario 2003-2013.

	Sudden cardiac death rate per 100,000		Relative reduction (95% CI)	Average annual decline, events per 100,000 (95% CI)
	2003	2013		
Overall	57.9	42.4	0.27 (0.23–0.30)	1.6 (1.3–1.8)
Sex				
Women	27.8	21.0	0.24 (0.17–0.31)	0.7 (0.6–0.8)
Men	88.6	64.1	0.28 (0.24–0.31)	2.5 (2.0–2.9)
Age				
35–49	15.2	12.9	0.15 (0.03–0.25)	0.3 (0.1–0.4)
50–59	53.4	41.4	0.22 (0.15–0.29)	1.1 (0.9–1.3)
60–64	101.7	76.3	0.25 (0.16–0.33)	2.8 (2.3–3.4)
65–69	139.6	102.9	0.26 (0.18–0.34)	3.6 (2.3–4.8)
70–74	217.7	136.2	0.37 (0.31–0.43)	7.8 (6.3–9.3)

Abbreviations: CI, confidence interval; SCD, sudden cardiac death, Ontario population aged > 35 years in 2003 = 6,269,742 and in 2013 = 7,229,963.

Discussion

Using a previously validated method to determine SCD incidence in the general population, we were able to generate new insights for this common and yet deadly condition. First, we observed a 27% relative reduction in SCD incidence over the past decade. Second, the most contemporary age and sex-standardized SCD rate among adults between 35–74 years was 42.4/100,000, but the SCD incidence varied substantially by age, sex, cardiac risk factors, and prior cardiac conditions. Third, the largest reductions in the SCD incidence over the past decade appeared to be among patients with heart failure. In contrast, the decline in SCD incidence was relatively low for patients with cardiac risk factors and no established disease.

Epidemiological surveillance of disease is important for the understanding and planning of public health services.[29,30] Although SCD is one of the leading causes of death in developed countries, the inability to apply the classic definition of unexpected death has hampered our understanding of this condition. One of the novelties of this study was our ability to circumvent this problem by applying a previously validated algorithm to routinely collected administrative data that are available in many countries. Although the incidence of SCD observed in our study appeared in line with prior reports from Japan and Australia, it was impossible to directly compare estimates from different countries because they used different methods to ascertain sudden death patients.[7,8] Indeed, Kong et al. have previously performed a systematic review to confirm our notion that the true incidence of SCD is not known because of a lack of standardization.[31] It is our hope that a method similar to what we used in our current study be adapted to allow cross country comparisons in the future.

Our study also differed from prior evaluations because we were able first to identify the population at risk and then determine the incidence of SCD in various subgroups. In contrast, other studies assembled cohorts of SCD patients, and then evaluated whether the risk profile of the deceased patients have changed over time.[6–8,32–36] This approach neglects the population changes in risk profile. For example, an increasing number of diabetics among SCD cohorts over time could be due to the increasing propensity of diabetics to suffer sudden death.[37] Alternatively, it could also be due to an increasing number of diabetics in the population.

Despite the lack of universally acceptable definition of SCD that could be used in epidemiological studies, our results on temporal trends are valid because the same methodology was applied in the entire study period. We observed the largest reduction of SCD incidence among patients with prior heart failure hospitalization. In fact, a recent study demonstrated ambulatory heart failure patients enrolled in clinical trials from 1995 to 2014 experienced a 44% decline in the rate of sudden death.[38] Our study extends their findings by demonstrating that the significant improvement seen in trial participants actually translated to the population at large. We also found potential reasons for such improvement as we observed an increased use of medical therapy, cardiac assessment, and cardiac invasive interventions during this study period.

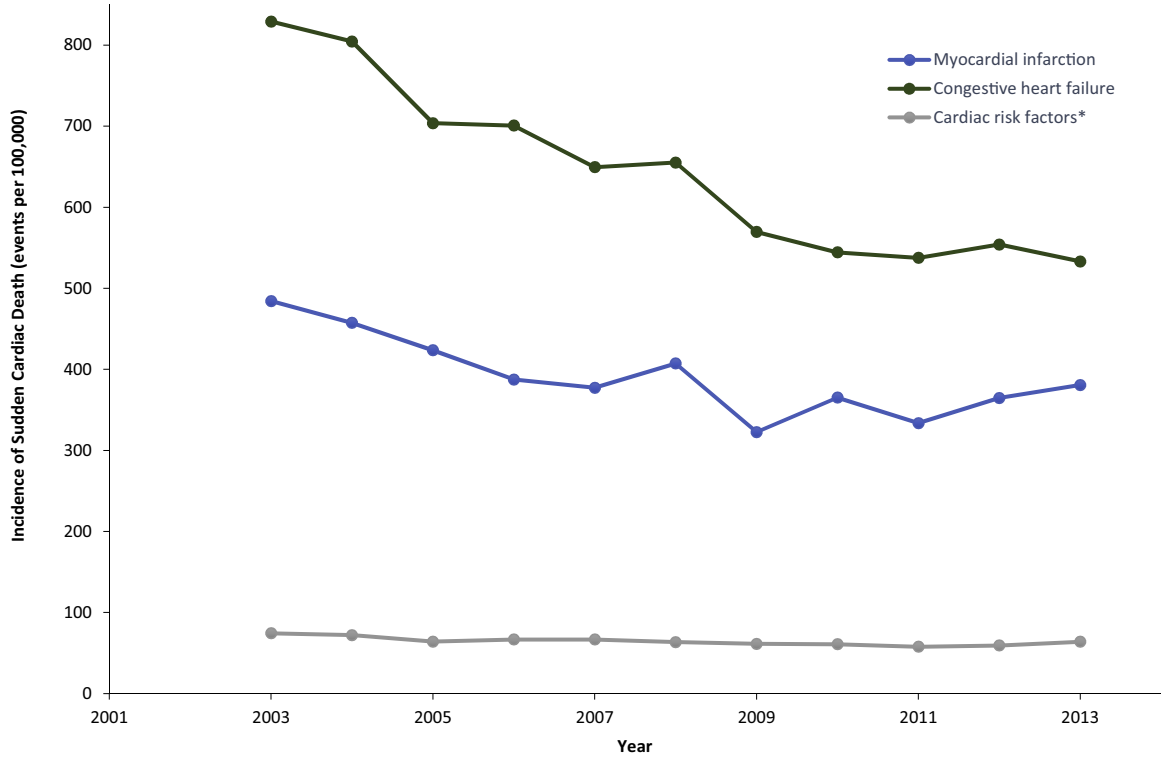
On the other hand, the reduction among patients with cardiac risk factors and no prior disease was relatively minor. Such discrepancy is likely related to the difficulty in predicting SCD among primary

Table 3 – Age and sex adjusted rates for sudden cardiac death in specified conditions, Ontario 2003-2013.

	Sudden cardiac death rate per 100,000		Relative reduction (95% CI)	Average annual decline, events per 100,000 (95% CI)
	2003	2013		
Cardiac risk factors[a]	74.5	63.9	0.14 (0.08–0.2)	1.3 (0.8–1.8)
Myocardial infarction	484.2	380.7	0.21 (0.08–0.32)	11.4 (5.9–17)
Heart failure	829.0	533.1	0.36 (0.28–0.42)	30.7 (24.8–36.5)

Abbreviations: CI, confidence interval.

[a] This group included patients with diabetes, hypertension, or hyperlipidemia but without history of myocardial infarction, congestive heart failure, atrial fibrillation, or ventricular arrhythmia. Ontario population aged 35+ years: 2003 = 6,269,742; 2013 = 7,229,963.



[a] This group included patients with diabetes, hypertension, or hyperlipidemia.

Fig. 2 – Trends of sudden cardiac death in patients with or without previous cardiac disease in Ontario, Canada 2003-2013. Trends in the incidence of sudden cardiac deaths over time are shown in patients with cardiac risk factors, myocardial infarction, and heart failure. Y axis shows the incidence of sudden cardiac deaths per 100,000, X-axis shows year of events.

prevention patients with cardiac risk factors. In addition, there is no specific treatment to lower the risk of SCD except control of risk factors. It is important to recognize that the total number of SCD events among primary prevention is large despite the lower incidence because of the large number of individuals who are affected by cardiac risk factors.

Several limitations of our study merit consideration. First, the majority of deaths were determined by death certificates given the small number of autopsies that are currently performed. Although it is likely that misclassification of causes of death has occurred, our methods represent the best possible mechanism to generate epidemiological data on the entire population. Second, our cohort was limited to a restricted age range between 35–74 years, and therefore, our findings cannot be applied beyond this age group. This restriction was necessary because the accuracy of determining SCD will be lower in younger subjects whose deaths may be related to substance abuse, and older subjects, who may have significant comorbidities and much fewer unexpected deaths.[39] Finally, we conducted this study in Ontario, Canada, and the findings and trends might not apply to other populations. However, it is our hope that similar methods could be applied to other countries to enable additional insights in SCD incidence around the world.

Conclusions

We showed a substantial decrease in SCD among patients with heart diseases, but relatively stable rates in primary prevention. These findings suggest that there is still a gap in prevention of SCD in people without heart disease. While guideline-based therapy improved outcomes among patients with cardiovascular history, prevention of SCD in the general population is still a challenge. It is more difficult to track patients at risk for SCD among patients with no heart disease and prevention strategies might be different than conventional cardiac care. Future investigations should strive to gain a better understanding of the pathogenesis and risk factors for SCD in a population, which will guide the development of policy and interventions to reduce the impact of this major public health issue.

Disclosures/Conflict of interest

This study was funded by an operation grant (MOP-312378) and a Foundation grant (FDN-154333) from the Canadian Institutes of Health Research.

Dr. Ko is supported by a Mid-Career Investigator Award from the HSF, Ontario Provincial Office. Dr. Dorian is a Network Investigator of the Cardiac Arrhythmia Network of Canada (CANet) and is supported by a CANet Program grant, as part of the Networks of Centres of Excellence (NCE). The other authors report no disclosures or conflicts.

Acknowledgment

This study was supported by the ICES, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care

(MOHLTC). The opinions, results, and conclusions reported in this article are those of the authors and are independent from the funding sources. No endorsement by ICES, or the MOHLTC is intended or should be inferred.

Parts of this material are based on data and information compiled and provided by CIHI. The analyses, conclusions, opinions and statements expressed herein are those of the author, and not necessarily those of CIHI.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.01.010.

REFERENCES

1. Hayashi M, Shimizu W, Albert CM. The spectrum of epidemiology underlying sudden cardiac death. Circ Res 2015;116:1887–906.
2. Deo R, Albert CM. Epidemiology and genetics of sudden cardiac death. Circulation 2012;125:620–37.
3. Berdowski J, Berg RA, Tijssen JGP, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: systematic review of 67 prospective studies. Resuscitation 2010;81:1479–87.
4. Chugh SS, Reinier K, Teodorescu C, et al. Epidemiology of sudden cardiac death: clinical and research implications. Prog Cardiovasc Dis 2008;51:213–28.
5. Zipes DP, Wellens HJ. Sudden cardiac death. Circulation 1998;98:2334–51.
6. Niemeijer MN, van den Berg ME, Leening MJ, et al. Declining incidence of sudden cardiac death from 1990-2010 in a general middle-aged and elderly population: the Rotterdam study. Heart Rhythm 2015;12:123–9.
7. Feng JL, Nedkoff L, Knuiman M, et al. Temporal trends in sudden cardiac death from 1997 to 2010: a data linkage study. Heart Lung Circ 2017;26:808–16.
8. Maruyama M, Ohira T, Imano H, et al. Trends in sudden cardiac death and its risk factors in Japan from 1981 to 2005: the Circulatory Risk in Communities Study (CIRCS). BMJ Open 2012;2:e000573.
9. Chan PS, McNally B, Tang F, Kellermann A. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation 2014;130:1876–82.
10. Grunau B, Kawano T, Dick W, et al. Trends in care processes and survival following prehospital resuscitation improvement initiatives for out-of-hospital cardiac arrest in British Columbia, 2006–2016. Resuscitation 2018;125:118–25.
11. Wong MK, Morrison LJ, Qiu F, et al. Trends in short- and long-term survival among out-of-hospital cardiac arrest patients alive at hospital arrival. Circulation 2014;130:1883–90.
12. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics—2012 update: a report from the American Heart Association. Circulation 2012;125:e2–e220.
13. Benjamin EJ, Virani SS, Callaway CW, et al. Heart disease and stroke statistics-2018 update: a report from the American Heart Association. Circulation 2018;137:e67–e492.
14. Tu JV, Khan AM, Ng K, Chu A. Recent temporal changes in atherosclerotic cardiovascular diseases in Ontario: clinical and health systems impact. Can J Cardiol 2017;33:378–84.
15. Wang Y, Lichtman JH, Dharmarajan K, et al. National trends in stroke after acute myocardial infarction among Medicare patients in the United States: 1999 to 2010. Am Heart J 2015;169: 78-85.e4.
16. Shah NS, Huffman MD, Ning H, Lloyd-Jones DM. Trends in myocardial infarction secondary prevention: the national health and nutrition examination surveys (NHANES), 1999–2012. J Am Heart Assoc 2015;4.
17. Danaei G, Finucane MM, Lu Y, et al. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2.7 million participants. Lancet 2011;378:31–40.
18. Menke A, Casagrande S, Geiss L, Cowie CC. Prevalence of and trends in diabetes among adults in the United States, 1988-2012. JAMA 2015;314:1021–9.
19. Lee DS, Chiu M, Manuel DG, et al. Trends in risk factors for cardiovascular disease in Canada: temporal, socio-demographic and geographic factors. CMAJ 2009;181:E55–66.
20. Tu JV, Chu A, Donovan LR, et al. The cardiovascular health in ambulatory care research team (CANHEART). Circ Cardiovasc Qual Outcomes 2015;8:204–12.
21. Ko DT, Alter DA, Guo H, et al. High-density lipoprotein cholesterol and cause-specific mortality in individuals without previous cardiovascular conditions: the CANHEART study. J Am Coll Cardiol 2016;68:2073–83.
22. Yan AT, Koh M, Chan KK, et al. Association between cardiovascular risk factors and aortic stenosis: the CANHEART aortic stenosis study. J Am Coll Cardiol 2017;69:1523–32.
23. Chung CP, Murray KT, Stein CM, Hall K, Ray WA. A computer case definition for sudden cardiac death. Pharmacoepidemiol Drug Saf 2010;19:563–72.
24. Ray WA, Chung CP, Murray KT, Cooper WO, Hall K, Stein C. Out-of-hospital mortality among patients receiving methadone for noncancer pain. JAMA Intern Med 2015;175:420–7.
25. Habel LA, Cooper WO, Sox CM, et al. Adhd medications and risk of serious cardiovascular events in young and middle-aged adults. JAMA 2011;306:2673–83.
26. Graham DJ, Ouellet-Hellstrom R, MaCurdy TE, et al. Risk of acute myocardial infarction, stroke, heart failure, and death in elderly Medicare patients treated with rosiglitazone or pioglitazone. JAMA 2010;304:411–8.
27. Ray WA, Murray KT, Hall K, Arbogast PG, Stein CM. Azithromycin and the risk of cardiovascular death. N Engl J Med 2012;366:1881–90.
28. Antoniou T, Hollands S, Macdonald EM, Gomes T, Mamdani MM, Juurlink DN. Trimethoprim–sulfamethoxazole and risk of sudden death among patients taking spironolactone. CMAJ 2015;187:E138.
29. German RR, Lee L, Horan J, Milstein R, Pertowski C, Waller M. Updated guidelines for evaluating public health surveillance systems. MMWR Recomm Rep 2001;50.
30. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Philadelphia, PA: Lippincott Williams & Wilkins; 2008.
31. Kong MH, Fonarow GC, Peterson ED, et al. Systematic review of the incidence of sudden cardiac death in the United States. J Am Coll Cardiol 2011;57:794–801.
32. Reinier K, Nichols GA, Huertas-Vazquez A, et al. Distinctive clinical profile of blacks versus whites presenting with sudden cardiac arrest. Circulation 2015;132:380–7.
33. Meyer L, Stubbs B, Fahrenbruch C, et al. Incidence, etiology, and survival trends from cardiovascular-related sudden cardiac arrest in children and young adults ages 0–35: a 30-year review. Circulation 2012;126:1363–72.
34. Hua W, Zhang LF, Wu YF, et al. Incidence of sudden cardiac death in China: analysis of 4 regional populations. J Am Coll Cardiol 2009;54:1110–8.
35. Messner T, Lundberg V. Trends in sudden cardiac death in the northern Sweden MONICA area 1985–99. J Intern Med 2003;253:320–8.
36. Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. Circulation 2001;104:2158–63.
37. Jouven X, Lemaître RN, Rea TD, Sotoodehnia N, Empana J-P, Siscovick DS. Diabetes, glucose level, and risk of sudden cardiac death. Eur Heart J 2005;26:2142–7.
38. Shen L, Jhund PS, Petrie MC, et al. Declining risk of sudden death in heart failure. N Engl J Med 2017;377:41–51.
39. Allan KS, Morrison LJ, Pinter A, Tu JV, Dorian P, Rescu Epistry I. "Presumed cardiac" arrest in children and young adults: a misnomer? Resuscitation 2017;117:73–9.