Sudden Natural Deaths in Ontario, Canada: A Retrospective Autopsy Analysis (2012–2016)

Jayantha C. Herath1,2, Olivia Liu3
1Ontario Forensic Pathology Service, 2Department of Laboratory Medicine and Pathobiology, University of Toronto, Toronto, 3Department of Anthropology (Forensic Science), University of Toronto Mississauga, Mississauga, ON, Canada

Abstract

This study was performed to identify the categories and distribution of sudden natural deaths (SNDs) in Ontario (ON) from January 2012 to December 2016 as no such reports have been published in ON, and the authors sought to find out the distribution of SND across ON by organ system, age, and sex. Three medicolegal databases were searched, and eight major categories of SND were identified and evaluated using multinomial logistic regression. During the 5-year period, 10,880 autopsies were performed on individuals aged 1–100, who died of sudden and natural causes. Over 800 causes of SNDs were recorded from January 2012 to December 2016. The largest category of SND was attributed to diseases and complications of the cardiovascular system (64.1%) followed by the respiratory system (9.1%), gastrointestinal system (6.9%), central nervous system (6.0%), metabolic diseases (3.8%), chronic alcoholism (3.5%), other (2.4%), infectious diseases (2.2%), and cancer (1.8%). The five most common causes of SND were also cardiovascular in origin, which included atherosclerotic heart disease (n = 2127, 19.5%), atherosclerotic and hypertensive heart disease (n = 711, 6.5%), myocardial infarction (n = 723, 6.6%), hypertensive heart disease (n = 518, 4.8%), and pulmonary embolism (n = 377, 3.5%). Determination of cause of death in natural deaths is an important part in death investigation, which can provide crucial information in the interest of public health by identifying public health risks and monitoring disease trends.

Keywords: Cause of death, epidemiology, forensic pathology, forensic science, Ontario, sudden natural death

Introduction

Sudden natural death (SND) occurs as a result of a preexisting disease.[1] While natural deaths are not typically the interest of medicolegal investigations, SND and unexpected natural deaths generate forensic interest because of their unexplained etiology. SNDs can be divided into three classifications: (i) instantaneous deaths, which occur when an individual suddenly collapses and dies; (ii) sudden deaths, which occur when an individual die within 1–24 h of the onset of symptoms; and (iii) unexpected deaths, when an otherwise healthy individual is discovered dead.[1] In Ontario (ON), SNDs comprise the largest category of death investigated by the Office of the Chief Coroner (OCC) and the Ontario Forensic Pathology Service (OFPS). In 2014, natural deaths accounted for 57% of cases.[2] Due to the large amount of cases attributed to sudden natural causes, the question remains: Why are people dying from unexpected diseases and can this be prevented? The first step in preventing SND is to identify which demographics are most affected and what diseases are responsible for these deaths.

The purpose of this research was to conduct a retrospective epidemiological study of the types and distribution of SNDs in ON. This was accomplished by reviewing data from January 2012 to December 2016 from three databases at the OFPS and identifying categories of SND for statistical analysis. The information gathered in this research will be used to assist in community forensic medicine, which aims to identify health problems in the community by examining disease trends in the deceased.[3] By determining which categories contribute to SNDs, prevention strategies can be developed to avoid deaths of a similar nature. The results of this study will contribute to one of the final steps in ON’s medicolegal death investigation.

Address for correspondence: Dr. Jayantha C. Herath, Ontario Forensic Pathology Service, University of Toronto, 25 Morton Shulman Avenue, Toronto, ON M3M 0B1, Canada. E-mail: jayantha.herath@ontario.ca

Submitted: 27-Nov-2019 Revised: 12-Feb-2020 Accepted: 17-Feb-2020 Published: 17-Mar-2020

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Herath JC, Liu O. Sudden natural deaths in Ontario, Canada: A retrospective autopsy analysis (2012–2016). J Forensic Sci Med 2020:6:18-26.
system, which seeks to improve public health and safety through the examination of case data.\[4\]

This study was based on medicolegal (forensic) cases referred to coroners. Deaths not referred to coroners are not included in this study. When cases are not referred to coroners, the death certificate is issued by the clinicians based on clinical findings, laboratory investigations, and imaging such as computed tomography and magnetic resonance imaging scans. In the medicolegal investigation of unnatural and unexplained deaths, forensic pathologists and coroners are responsible for determining the cause and manner of death of the deceased. This is accomplished through a detailed death investigation including a postmortem examination of the body and the analysis of autopsy findings and laboratory tests.\[1\] The manner of death explains how the cause of death (COD) came about and can be classified into five categories.\[1\] These categories include natural, accidental, suicide, homicide, or undetermined deaths. COD is any injury or disease that produces a physiological derangement in the body that results in the death of the individual.\[1\] In most cases of SND, the COD is often the result of an underlying cardiovascular disease leading to sudden cardiac death (SCD). Cardiovascular diseases affect 17 million people a year worldwide and contribute to 25% of SNDs.\[3\] In individuals <30 years, SNDs are often due to hereditary cardiovascular diseases.\[6\] In these cases, individuals are less likely to show symptoms prior to death, and there are often no macroscopic autopsy findings.\[5,7-9\]

Most research has focused on SCDs in younger individuals due to the ambiguity surrounding these cases and the greater socioeconomic impacts of young deaths.\[10\] Consequently, SND studies rarely encompass deaths that are not cardiovascular in origin, overlooking all other possible contributions to SND. Furthermore, when all types of SNDs are considered, very few publications examine large populations encompassing all ages.\[11-14\] Many of these articles are published outside of Canada and only exist in ON, but it is limited to SCDs in young individuals <40 years.\[13\] Nevertheless, the results of these studies have been rather uniform in their findings, with cardiovascular diseases resulting in the most frequently affected organ system\[12,17,19,20\] and atherosclerosis as the most common COD.\[12,15,16\] However, some have reported hypertensive heart disease as the most prevalent COD\[13,19,20\] and even presumed arrhythmia.\[17,13\] Finally, most studies show that SNDs are more common among males than females.\[11-19\]

This research sought to determine the categories and distribution of SNDs among males and females in ON, as well as the causes and distribution of SNDs in different ages and locations. Two hypotheses were proposed for this research: (i) there will be no associations between SND and the variables of sex, age, region, and year and (ii) the probability of SND, when compared to cardiovascular system (CVS) death, was the same for sex, age, region, and year. The alternative hypotheses are as follows: (i) there are associations between SND and the variables of sex, age, region, and year and (ii) the probability of SND, when compared to CVS death, was not the same for sex, age, region, and year.

In this study, atherosclerotic heart disease was used in pathologic conditions where COD is due to pure coronary artery atherosclerosis and chronic changes of heart. The term, myocardial infarction, was used only when acute microscopic evidence of myocardial infarction was present. When hypertensive changes are present without significant coronary artery disease, the term hypertensive heart disease was used. When both hypertensive heart disease and significant coronary atherosclerosis co-exist, the terms atherosclerotic and hypertensive heart disease were used. Hypertensive heart disease was excluded from cardiomyopathies for the purpose of this study. In Canada, deaths due to acute substance abuse do not categorize under SNDs. Deaths due to acute substance abuse are categorized as accidental deaths and are not included in this study.

**Ethics**

Approval for this study was granted by the University of Toronto Mississauga Ethics Review Committee and the OFPS Ethics Board upon completion and review of the Undergraduate Ethics Review Protocol Form: Student-Initiated Forensic Project for the University of Toronto Mississauga. All information required for this study was collected by request, thereby restricting access to the databases and their content to members of the OCC and OFPS. In doing this, only information that was required for the research was available for the study and any personally identifiable and private information remained confidential.

**Materials and Methods**

This research involved the secondary analysis of previously collected information on natural deaths in ON between January 2012 and December 2016 from the following three databases: F-Path (managed by the Toronto Forensic Unit), Provincial Information Management System (managed by the OFPS), and Coroner’s Information System (managed by the OCC). All nontraumatic deaths that were admitted into these databases were considered to be SNDs due to the lack of certainty regarding the COD prior to autopsy. A total of 11,849 SNDs were identified, and the following information was provided from each case: sex, age at death, year of death, region of death, immediate COD, and antecedent COD 1 and 2. Each case was manually assessed to ensure that all required information was available. Cases that were missing any of the required variables were omitted from the study. In addition, cases were excluded if the immediate COD was due to nonnatural causes, surgical complications, or if the COD was uncertain/unknown. Lastly, only individuals between the ages of 1 and 100 years were utilized in this study. This resulted in a final dataset of 10,880 cases.

Each COD statement was manually reviewed and renamed to ensure that each disease would be identified by a single...
title (e.g., coronary artery disease, coronary atherosclerosis, or coronary heart disease were renamed atherosclerotic heart disease). Standardizing the COD was completed to ensure that the total number of deaths attributed to a single disease was not underestimated and to allow for an easier identification of SND category. However, in some instances, multiple immediate CODs were provided. In these cases, the first listed COD was selected as the immediate COD, unless the combination of causes originated within the same organ system or disease process. Therefore, this study is biased toward single-organ system or single-disease process deaths. It was also found that some cases provided the mechanism of death (MOD) as the immediate COD. As the MOD (e.g., bleeding) does not accurately represent COD, it was substituted with antecedent COD (antecedent COD 2 was selected if antecedent COD 1 was also a MOD). Once the review was complete, each case was classified according to the organ system or disease process involved in the death of the individual for statistical analyses. In total, nine categories of SND were identified, including CVS, respiratory system (RS), gastrointestinal (GIS), central nervous system (CNS), metabolic disease (MD), infectious diseases (ID), cancer (CAN), chronic alcoholism (CA), and other (O) category for all other organ system or disease processes containing <100 cases. The assignment of the COD to an organ system or disease process was then reviewed by an experienced expert in forensic pathology (X). One additional variable was created to examine the differences between young (<40 years) and old (>40 years) age groups following Pilmer et al.’s[18] standards.

Statistical analysis
Statistical analyses were conducted on IBM SPSS Statistics for Windows (Version 24.0. Armonk, NY, IBM Corp., IBM). All cases (n = 10,880) were examined using multinomial logistic regression (MLR) to determine if an association exists between SND, when compared to CVS deaths, and the variables of sex, age, region, and year. P ≤ 0.05 was used to determine the significance of the results for the MLR tests. MLR utilizes an independent predictor variable that exists on a continuous or nominal scale to evaluate the probability of an event occurring in three or more dependent categorical variables.[21] Within the model, the dependent categorical variables were compared against CVS deaths. CVS was selected as the reference group as it is known to be the leading cause of SND and because it is the largest category within the dataset. The “Factor” variables included sex, young/old age groups, and year. The “Covariate,” which is used for continuous data, included the variable year. For the purposes of this study, only the main effects of the model were assessed.

Two tests were performed using MLR to assess the relationship between four predictors and nine categorical groups of SND. The first test examined the following predictor variables: males compared to females, >40 years compared to <40 years, all regions compared to the central region, and year within the specified category of SND compared to CVS. The second test was performed to examine any variables that were not assessed in the first model. The following predictor variables were studied: females compared to males, <40 years compared to >40 years, all regions compared to the western region, and year within the specified category of SND compared to CVS. This difference could be due to various factors such as ethnic background, food habits, and socioeconomic status, but a population study of regions was not done to provide to explain this difference.

To determine if the models were of good fit, the “Model Fitting Summary” for predictor variables was examined. A “Final Model” of P ≤ 0.05 was used to determine significance.[21] In addition, the “Goodness-of-Fit” for predictor variables was also evaluated. A Pearson’s Chi-square and deviance Chi-square of P ≥ 0.05 were used to assess significance and good fit of the data.[21] The overall effect of the predictor variables was evaluated in the “Likelihood Ratio Tests.” P ≤ 0.05 was used to determine significance.[21] The “Classification Table” was used to assess the model’s percentage of accuracy. If the model performed well, the B-value, odds ratio (OR), and the 95% confidence interval (95% CI) were recorded for each significant variable.

Results
Demographic overview
During the 5-year period, 10,880 autopsies were performed on individuals aged 1–100 who had died of sudden and natural causes. The overall number of cases has gradually increased over the years [Table 1]. Nearly 67.1% of cases were attributed to male deaths (n = 7297) and 32.9% were attributed to female deaths (n = 3583) [Table 2]. The mean age at death was 56 ± 15.3 years, with most deaths occurring between 51 and 60 years of age (n = 3340, 30.7%) [Table 3]. Almost 12.4% of the cases were <40 years (n = 1348) and 87.6% were >40 years (n = 9532) [Table 3]. When the total number of deaths was evaluated by region, the central region contributed to 42.2% of deaths (n = 4590) [Table 4].

Leading causes of sudden natural death
Over 800 causes of SNDs were recorded in ON from January 2012 to December 2016. The largest category of SND was attributed to diseases and complications of the CVS (64.1%) followed by the RS (9.1%), GIS (6.9%), CNS (6.0%), MD (3.8%), CA (3.5%), O (2.4%), ID (2.2%), and

| Table 1: Distribution of sudden natural death by year |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| CV S | RS | GIS | CNS | MD | CA | O | ID | CAN | Total |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 2012  | 1270 | 196 | 152 | 139 | 53  | 55  | 45  | 40  | 33   | 1983  |
| 2013  | 1388 | 204 | 150 | 131 | 81  | 75  | 48  | 38  | 31   | 2146  |
| 2014  | 1329 | 177 | 141 | 128 | 104 | 79  | 56  | 50  | 39   | 2103  |
| 2015  | 1354 | 193 | 148 | 111 | 90  | 84  | 48  | 54  | 63   | 2145  |
| 2016  | 1636 | 226 | 165 | 154 | 84  | 87  | 63  | 53  | 35   | 2503  |
| Total | 6977 | 996 | 756 | 663 | 412 | 380 | 260 | 235 | 201  | 10880 |

CVS: Cardiovascular system, RS: Respiratory system, GIS: Gastrointestinal system, CNS: Central nervous system, MD: Metabolic diseases, O: Other, CA: Chronic alcoholism, ID: Infectious diseases, CAN: Cancer
CAN (1.8%). The five most common causes of SND were also cardiovascular in origin, which included atherosclerotic heart disease (n = 2127, 19.5%), atherosclerotic and hypertensive heart diseases (n = 711, 6.5%), myocardial infarction (n = 723, 6.6%), hypertensive heart disease (n = 518, 4.8%), and pulmonary embolism (n = 377, 3.5%).

When the leading causes of SND were evaluated between young and old age groups, it was found that the CNS, MD, and CVS contributed to the leading causes of SND in individuals <40 years, namely epilepsy (n = 110/1348), atherosclerotic heart disease (n = 82/1348), diabetic ketoacidosis (n = 71/1348), pulmonary embolism (n = 58/1348), and pulmonary thromboembolism (n = 55/1348). However, the leading causes of SND >40 years were the same as the overall leading causes of SNDs as follows: atherosclerotic heart disease (n = 2045/9532), atherosclerotic and hypertensive heart diseases (n = 685/9532), myocardial infarction (n = 677/9532), hypertensive heart disease (n = 477/9532), and pulmonary embolism (n = 319/9532).

CVS diseases contributed to the leading causes of SND for both sexes. The leading causes for males included atherosclerotic heart disease (n = 1622/7297), atherosclerotic and hypertensive heart disease (n = 582/7297), myocardial infarction (n = 556/7297), hypertensive heart disease (n = 340/7297), and ischemic heart disease (n = 226/7297). The leading causes for females included atherosclerotic heart disease (n = 504/3583), pulmonary embolism (n = 193/3583), hypertensive heart disease (n = 179/3583), myocardial infarction (n = 167/3583), and pulmonary thromboembolism (n = 141/3583). Pulmonary embolism is the sudden blockage of a major blood vessel (pulmonary artery and branches) in the lung, usually by a blood clot. Please note, pulmonary thromboembolism refers to pulmonary embolism in this study. We have used both terms as different pathologists have used this term for the same disease pathologic condition.

It is important to note that while atherosclerotic heart disease is the most common cause of SND, its impact is likely greater than the number previously presented, as it appears in conjunction with many other cardiovascular diseases (n = 767). However, as the purpose of this study is to evaluate which organ systems or disease processes are affected in the process of SND rather than to evaluate individual causes, this should not affect the results of the analyses. Additional information regarding the leading COD within each category of SND is listed in Table 5.

### Statistical results

The model fitting information for both tests indicated that the final models were statistically significantly improved over the null, Chi-square (48, n = 10,880) = 578.27, P = 0.000.
The classification table revealed that the overall accuracy of the tests was 64.1%. The likelihood ratio tests revealed that sex, > or <40-year age groups, and region were found to significantly influence the occurrence of SND [Table 6].

The following contains interpretations for Tables 6-8. Males were more likely to die of CVS deaths than females. Individuals that were >40 years were more likely than to die from CVS deaths than individuals <40 years, with the exception of CAN. Individuals who lived in the western region were more likely to die of CVS than CAN when compared to those living in the central region. Individuals who lived in the northern region were less likely to die of CAN than RS when compared to those living than in the central region.

The following contains interpretations for Table 8. Females were more likely to die of non-CVS death than males. Individuals <40 years were also more likely to die from non-CVS deaths than individuals >40 years, with the exception of CAN. Individuals living in the central and eastern regions were more likely to die from CAN than CVS when compared to those living in the western region. Individuals living in the northern region were more likely to die from CVS than CA when compared to those living in the western region.

Specific OR and percentage odds are provided in Tables 7 and 8. Age was not found to significantly influence death by CA or GIS in either analysis.

Some significantly large OR values were also identified. Individuals >40 years were 2.484 times more likely than individuals <40 years to die from CAN than CVS [Table 7]; individuals <40 years were 4.420 times more likely to die from CNS than CVS; females were 2.496 times more likely than males to die from ID; individuals <40 years were 2.776 times more likely than individuals >40 to die from ID; females were 2.476 times more likely than males to die from O; individuals <40 years were 3.261 times more likely to die from O than individuals >40 years [Table 8].

**Discussion**

Eight major categories of SND were identified, including: CVS, RS, GIS, CNS, MD, ID, CA, and CAN. The demographic data revealed that most deaths were caused

### Table 5: Leading causes of death by sudden natural death categories

| Category of SND | Subcategory | Number of males | Number of females | Total (percentage of all cases, n=10,880) |
|-----------------|-------------|-----------------|------------------|----------------------------------------|
| CVS             | Atherosclerotic heart disease | 1436 | 426 | 2127 (19.5) |
|                 | Atherosclerotic and hypertensive heart diseases | 577 | 128 | 705 (6.5) |
| RS              | Pneumonia (NOS) | 186 | 112 | 298 (2.7) |
|                 | Bronchopneumonia (NOS) | 152 | 96 | 248 (2.3) |
| GIS             | Gastrointestinal hemorrhage | 191 | 71 | 262 (2.4) |
|                 | Peritonitis (NOS) | 48 | 35 | 83 (0.8) |
| CNS             | Epilepsy | 125 | 73 | 198 (1.8) |
|                 | Subarachnoid hemorrhage | 58 | 52 | 110 (1.0) |
| MD              | Diabetic ketoacidosis | 175 | 114 | 289 (2.7) |
|                 | Ketoacidosis (NOS) | 31 | 19 | 50 (0.5) |
| CA              | Chronic alcoholism | 107 | 68 | 175 (1.6) |
|                 | Alcoholic ketoacidosis | 85 | 47 | 132 (1.2) |
| O               | Shock (septic) | 15 | 22 | 37 (0.3) |
|                 | Pyelonephritis | 10 | 15 | 25 (0.2) |
| ID              | Sepsis | 63 | 63 | 126 (1.6) |
|                 | Septicemia | 23 | 24 | 47 (0.4) |
| CAN             | Carcinoma (lung) | 34 | 15 | 49 (0.5) |
|                 | Carcinoma (breast) | 0 | 13 | 13 (0.1) |

NOS: Not otherwise specified, SND: Sudden natural death, CVS: Cardiovascular system, RS: Respiratory system, GIS: Gastrointestinal system, CNS: Central nervous system, MD: Metabolic diseases, O: Other, CA: Chronic alcoholism, ID: Infectious diseases, CAN: Cancer

### Table 6: Likelihood ratio tests

| Effect                                | Model fitting criteria | Likelihood ratio tests |
|---------------------------------------|------------------------|------------------------|
|                                       | −2 log likelihood of reduced model | | \( \chi^2 \) | df | Significance |
| Intercept                             | 2404.792               | 0.000 | 0 | 0.000 |
| Sex                                   | 2561.891               | 157.098 | 8 | 0.000 |
| > or <40-year age groups              | 2755.057               | 350.264 | 8 | 0.000 |
| Region                                | 2448.731               | 43.939 | 24 | 0.008 |
| Year                                  | 2413.47                | 8.678 | 8 | 0.370 |
Herath and Liu: Sudden natural deaths in Ontario (2012-2016)

by cardiovascular-related diseases, which occurred most frequently in males and individuals aged >40 years. When examined using MLR, sex and age were found to be significantly correlated to SND. The analysis indicated that males and individuals aged >40 years are at a greater risk of CVS deaths, whereas females and individuals aged <40 years are at a greater risk of a wider range of SNDs than males and individuals aged >40 years. Before the age of 40, there are more deaths due to cardiovascular causes in men. After 40–50 years, there is no significant difference between deaths associated due to cardiovascular causes between men and women. This may be due to menopause. However, the following two exceptions were identified: individuals >40 years were more likely to die of CAN rather than CVS, whereas individuals <40 years were more likely to die of CVS diseases and/or complications.
The prevalence of CVS-related SND is a well-established fact, which was also supported in this study.\cite{13-17,19,20} Pelemo et al.\cite{13} have suggested that the incidence of CVS deaths may be related to the dietary practices of the Western world. After identifying a lower mean age at death when compared to earlier studies in the same region, they concluded that increasing urbanization and Westernization might have resulted in the decreased mean age at death.\cite{13} Indeed, nutritional and biomedical research has determined that the Western diet is a contributor to poor health.\cite{22,23} The Western diet, which includes increased consumption of red meats, carbohydrates, and fat with little intake of vegetables and fruits, has been found to be associated with a greater risk of cardiovascular diseases, cancer, obesity, and other chronic diseases.\cite{22-29} Contrarily, plant-based diets rich in vegetables, fruits, and whole grains have been found to be important factors in preventing chronic diseases.\cite{22-29}

Recently, Canada has implemented a new food guide that focuses on the portion-controlled consumption of plant-based foods over the traditional Western diet.\cite{30} It is possible that if these food guides are followed, SND rates may decrease. However, eating is a very individual preference, and eating healthy can be difficult when nutrient-poor foods have become more readily available and inexpensive. Furthermore, diet is only one component in a combination of lifestyle choices that influence overall health.\cite{31} With advancements in technology, people have become less active; when combined with unhealthy food choices and increased serving sizes, the risk of developing a chronic disease increases.\cite{27} Unhealthy lifestyle choices, such as drinking and smoking, are also prevalent within the society, and these choices can produce or exacerbate chronic conditions. Nevertheless, the promotion of healthier lifestyles is a manageable process that may aid in the decrease of SNDs.

However, genetic factors, which were not explored in this study, also constitute a risk factor for SND. Undiagnosed heritable diseases often result in the death of younger individuals, especially among CVS diseases.\cite{6} Heritable diseases are a concern as they can occur without symptoms.\cite{5,7-9} Furthermore, the presence of a heritable disease suggests that other family members and/or relatives may be at risk for the disease. As such, early screening of diseases should be performed to avoid deaths of this nature.

It was also found that individuals aged >40 years were 2.48 times more likely to die of CAN deaths versus CVS death. This correlation is consistent with the 2017 Canadian Cancer Statistics, which found that individuals >50 years are at a 90% greater chance of developing cancer and 96% greater chance of CAN deaths than individuals aged <50 years.\cite{32} When the COD data were reviewed, it was found that lung carcinoma contributed to the largest amount of CAN death in individuals aged >40 years (n = 49/193). This, too, is consistent with the 2017 Canadian Cancer Statistics, which found that more than 25% of CAN deaths in Canada are associated with lung CAN.\cite{32} MLR analysis also revealed that individuals living in the central and eastern regions of ON were 1.69 times more likely to die of CAN than CVS death. Prevention suggestions include screening beginning at the age of 40 to detect any early stages of cancer.

Individuals aged <40 years were found to be 4.42 times more likely to die of CNS deaths rather than CVS death. The COD data revealed that epilepsy contributed to 52.4% of all <40-year cases for CNS death. Furthermore, epilepsy was identified as the leading COD between all SNDs for individuals aged <40 years. The large number of cases attributed to epilepsy suggests that it is the COD influencing the likelihood of death to be greater within CNS deaths than CVS deaths within <40-year age groups. Sudden unexpected death in epilepsy (SUDEP) is a phenomenon that typically occurs in individuals who suffer from epilepsy. Studies have found that the probability of SUDEP increases with age and is significantly affected by comorbidities, or preexisting conditions, such as cardiac abnormalities due to genetic conditions or mutations.\cite{33,34} Research on antiepileptic drugs, however, has shown a significant improvement in the prevention of SUDEP.\cite{35} Therefore, prevention strategies should be put forward to promote antiepileptic drug use or medical alert systems, especially in individuals prone to epilepsy.

Females and individuals <40 years were found to be 2.496 and 2.776 times, respectively, more likely to die from ID compared to CVS death. The leading COD within this category was septicemia, which accounted for 68.8% of female CNS deaths and 62.9% of all <40-year CNS deaths. A comprehensive study was not done to find out the difference of septicemia between men and women. One reason for the higher incidence of septicemia in women may be due to gynecological/obstetric causes. Septicemia refers to the infection of the blood and can be caused by a multitude of factors. One way to avoid this is by cleaning any open wounds shortly afterward to avoid infection. Therefore, the promotion of personal hygiene and education in first-aid treatment should be suggested to avoid septicemia deaths. However, further investigation should be made to determine the cause of the infections, especially if the COD is not due to an external injury.

Unlike the other categories of death, O category contains a number of cases from various organ systems or disease processes. As a result, it is not possible to identify any particular COD that would likely influence an individual being in the O category. Therefore, prevention strategies should focus on healthier lifestyle choices as suggested previously and the early screening to avoid deaths of diseases within this category.

Some limitations were present in this study. The assignment of SND category was sometimes difficult. As COD statements are not limited to single-system or single-disease process deaths, a manual review of the data was required to ensure that all CODs fulfilled these requirements. This was completed to allow for an easier identification of the SND category. When COD statements included more than one system or disease
processes, they were edited to only include the first COD as the immediate COD. This was performed as the first ordered COD is usually the immediate COD. Regardless, this procedure may have resulted in some inconsistencies with the data and should have been included as their own category of SND. Future research should also consider including categories for multi-system or multi-disease process deaths. Categorizing deaths within SND type was also sometimes problematic when the COD involved two organ systems (i.e., hemorrhage involving CVS due to underlying disease is a cancer originating from a different organ system).

The results of this research present the first comprehensive and systematic review of the categories and distribution of SNDs in ON. By understanding the different categories of SND and identifying the affected demographic factors, strategies can be developed to avoid preventable natural deaths. Particular demographics, such as those identified with an OR ≥2.0, should be further examined. Although some suggestions were made to reduce the number of SNDs, these suggestions are preliminary, and more research should evaluate the individual causes within each category of SND to determine appropriate actions. Future research should be directed toward monitoring SND in ON and determining if other factors, such as heritability, economic status, or preexisting conditions, have any effect on the occurrence of SND. Research within other provinces and territories should also be performed to allow for a comparison of SND rates and categories, which could be used in a meta-analysis to examine SND within Canada.

**Conclusion**

During a 5-year period (2012–2016), 10,880 autopsies were performed on individuals aged 1–100 who had died of sudden and natural causes. Over 800 causes of SNDs were recorded. The largest category of SND was attributed to diseases and complications of the CVS (64.1%) followed by the RS (9.1%), GIS (6.9%), CNS (6.0%), MD (3.8%), CA (3.5%), O (2.4%), ID (2.2%), and cancer (1.8%). The five most common causes of SND were also cardiovascular in origin, which included atherosclerotic heart disease (n = 2127, 19.5%), atherosclerotic and hypertensive heart diseases (n = 711, 6.5%), myocardial infarction (n = 723, 6.6%), hypertensive heart disease (n = 518, 4.8%), and pulmonary embolism (n = 377, 3.5%).

Future research should be directed toward monitoring SND in ON and rest of the Canada, determining if other factors, such as heritability, economic status, or pre-existing conditions, have any effect on the occurrence of SND. Determination of COD in natural deaths, particularly when the death occurred suddenly, unexpectedly, or in the young, is an important part in death investigation. Performance of a complete death investigation including a thorough autopsy on apparent natural deaths can provide invaluable information in the interest of public health by identifying public health risks and monitoring disease trends.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. DiMaio VJ, DiMaio D. Forensic Pathology. 2nd ed. Boca Raton, Florida: CRC Press; 2001.

2. Available from: https://www.mcscs.jus.gov.on.ca/english/DeathInvestigations/OfficeChiefCoroner/Publicationsreports/OCCAnnualReport2012%E2%80%932015.html. [Last accessed on 2018 Nov 11].

3. Payne-James J, Busuttil A, Smock W. Forensic Medicine: Clinical and Pathological Aspects. San Francisco, CA: Greenwich Medical Media; 2002.

4. Available from: https://www.mcscs.jus.gov.on.ca/english/DeathInvestigations/Outcommitment/DI_Strat_plan_15_20.html. [Last accessed on 2018 Nov 11].

5. Basso C, Aguilera B, Banner J, Cohle S, d’Amati G, de Gouveia RH, et al. Guidelines for autopsy investigation of sudden cardiac death: 2017 update from the Association for European Cardiovascular Pathology. Virchows Arch 2017;471:691-705.

6. Adagbas AS, Uepeker RV, Roger VL, Gersh BJ. Sudden cardiac death: Epidemiology and risk factors. Nat Rev Cardiol 2010;7:216-25.

7. Jayaraman R, Reiner K, Nair S, Aro AL, Uy-Evanoado A, Rusinariu C, et al. Risk factors of sudden cardiac death in the young. Circulation 2018;137:1561-70.

8. Marijon E, Uy-Evanoado A, Dumas F, Karam N, Reiner K, Teodorescu C, et al. Warning symptoms are associated with survival from sudden cardiac arrest. Ann Intern Med 2016;164:23-9.

9. Basso C, Carturan E, Pilelhou K, Rizzo S, Corrado D, Thiene G. Sudden cardiac death with normal heart: Molecular autopsy. Cardiovasc Pathol 2010;19:321-5.

10. Deo R, Albert CM. Epidemiology and genetics of sudden cardiac death. Circulation 2012;125:620-37.

11. Escoffery CT, Shirley SE. Causes of sudden natural death in Jamaica: A medicolegal (coroner’s) autopsy study from the University Hospital of the West Indies. Forensic Sci Int 2002;129:116-21.

12. Zhao P, Wang JG, Gao P, Li X, Brewer R. Sudden unexpected death from natural diseases: Fifteen years’ experience with 484 cases in Seychelles. J Forensic Leg Med 2016;37:33-8.

13. Pelermo OE, Sabageh D, Kormolofo AO, Sabageh AO, Odesamni WO. An autopsy review of sudden unexpected natural deaths in a suburban Nigerian population. Popul Health Metr 2014;12:1-6.

14. Akan MD. Sudden natural deaths in Edirne, Turkey, from 1984 to 2005. Med Sci Law 2007;47:147-55.

15. Drory Y, Turetz Y, Hiss Y, Lev B, Fisman EZ, Pines A, et al. Sudden unexpected death in persons <40 years of age. Am J Cardiol 1991;68:1388-92.

16. Anderson RE, Hill RB, Broudy DW, Key CR, Pathak D. A population-based autopsy study of sudden, unexpected deaths from natural causes among persons 5 to 39 years old during a 12-year period. Hum Pathol 1994;25:1332-40.

17. Puranik R, Chow CK, Dufloiu JA, Kilbourn MJ, McGuire MA. Sudden death in the young. Heart Rhythm 2005;2:1277-82.

18. Pilmer CM, Porter B, Kish JA, Hicks AL, Gledhill N, Jannik V, et al. Scope and nature of sudden cardiac death before age 40 in Ontario: A report from the cardiac death advisory committee of the office of the chief coroner. Heart Rhythm 2013;10:517-23.

19. Obiorah CC, Amakiri CN. Review of population based coroners autopsy findings in Rivers state of Nigeria. Forensic Sci Int 2013;233:1-6.

20. Amakiri CN, Akang EE, Aghadime PU, Odesamni BO. A prospective study of coroner’s autopsies in University College Hospital, Ibadan, Nigeria. Med Sci Law 1997;37:69-75.

21. Chan YH. Biostatistics 305. Multinomial logistic regression. Singapore Med J 2005;46:259-68.

22. Martin C, Zhang Y, Tonelli C, Petroni K. Plants, diet, and health. Annu Rev Plant Biol 2013;64:19-46.

23. Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, et al. Origins and evolution of the Western diet: Health implications for the 21st century. Am J Clin Nutr 2005;81:341-54.
24. Oikonomou E, Psaltopoulou T, Georgiopoulos G, Siasos G, Kokkou E, Antonopoulos A, et al. Western Dietary Pattern Is Associated With Severe Coronary Artery Disease. Angiology 2018;69:339-46.
25. Mahe G, Ronziere T, Laviolle B, Gollier V, Cochery T, De Bray JM, et al. An unfavorable dietary pattern is associated with symptomatic ischemic stroke and carotid atherosclerosis. J Vase Surg 2010;52:62-8.
26. Adriouch S, Lelong H, Kesse-Guyot E, Baudry J, Lampuré A, Galan P, et al. Compliance with nutritional and lifestyle recommendations in 13,000 patients with a cardiometabolic disease from the Nutrinet-Santé study. Nutrients 2017;9. pii: E546.
27. Hariharan D, Vellanki K, Kramer H. The Western Diet and Chronic Kidney Disease. Curr Hypertens Rep 2015;17:16.
28. Medina-Remón A, Kirwan R, Lamuela-Raventós RM, Estruch R. Dietary patterns and the risk of obesity, type 2 diabetes mellitus, cardiovascular diseases, asthma, and neurodegenerative diseases. Crit Rev Food Sci Nutr 2018;58:262-96.
29. Myles IA. Fast food fever: Reviewing the impacts of the Western diet on immunity. Nutr J 2014;13:61.
30. Available from: https://food-guide.canada.ca/en/healthy-food-choices/. [Last accessed on 2019 Mar 29].
31. Klurfeld DM, Kritchevsky D. The Western diet: An examination of its relationship with chronic disease. J Am Coll Nutr 1986;5:477-85.
32. Available from: https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/canadian-cancer-statistics.html. [Last accessed on 2019 Mar 30].
33. Holst AG, Winkel BG, Risgaard B, Nielsen JB, Rasmussen PV, Haunsø S, et al. Epilepsy and risk of death and sudden unexpected death in the young: A nationwide study. Epilepsia 2013;54:1613-20.
34. Surges R, Sander JW. Sudden unexpected death in epilepsy: Mechanisms, prevalence, and prevention. Curr Opin Neurol 2012;25:201-7.
35. Ryvlin P, Cucherat M, Rheims S. Risk of sudden unexpected death in epilepsy in patients given adjunctive antiepileptic treatment for refractory seizures: A meta-analysis of placebo-controlled randomised trials. Lancet Neurol 2011;10:961-8.