American Journal of Emergency Medicine 33 (2015) 1140–1145

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

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

Original Contribution

Carbon monoxide poisoning deaths in the United States, 1999 to 2012☆,☆☆

Kanta Sircar, PhD [a,*], Jacquelyn Clower, MPH [b], Mi kyong Shin, DPH [c], Cathy Bailey, MS [a], Michael King, PhD [d], Fuyuen Yip, PhD [a]

[a] Air Pollution and Respiratory Health Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, Chamblee, GA 30341
[b] Cazador Contractor, Herndon, Virginia, United States
[c] Environmental Public Health Tracking, Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, Chamblee, GA 30341
[d] Epidemiology Workforce Branch, Division of Scientific Education and Professional Development, Center for Surveillance, Epidemiology and Laboratory Service, Centers for Disease Control and Prevention, Chamblee, GA 30341

ARTICLE INFO

Article history:
Received 11 February 2015
Received in revised form 30 April 2015
Accepted 7 May 2015

ABSTRACT

Background: Unintentional, non-fire related (UNFR) carbon monoxide (CO) poisoning deaths are preventable. Surveillance of the populations most at-risk for unintentional, non-fire related (UNFR) carbon monoxide (CO) poisoning is crucial for targeting prevention efforts.
Objective: This study provides estimates on UNFR CO poisoning mortality in the United States and characterizes the at-risk populations.
Methods: We used 1999 to 2012 data to calculate death rates. We used underlying and multiple conditions variables from death records to identify UNFR CO poisoning cases.
Results: For this study, we identified 6136 CO poisoning fatalities during 1999 to 2012 resulting in an average of 438 deaths annually. The annual average age-adjusted death rate was 1.48 deaths per million. Fifty four percent of the deaths occurred in a home. Age-adjusted death rates were highest for males (2.21 deaths per million) and non-Hispanic blacks (1.74 deaths per million). The age-specific death rate was highest for those aged ≥85 years (6.00 deaths per million). The annual rate of UNFR CO poisoning deaths did not change substantially during the study period, but we observed a decrease in the rate of suicide and unintentional fire related cases.
Conclusion: CO poisoning was the second most common non-medicinal poisonings death. Developing and enhancing current public health interventions could reduce ongoing exposures to CO from common sources, such as those in the residential setting.

Published by Elsevier Inc.

1. Introduction

Carbon monoxide (CO) is a toxic, colorless, odorless gas that is a product of combustion [1] Common symptoms of CO exposure include headache, dizziness, fatigue, nausea, vomiting, and chest pain. CO is particularly dangerous because it is imperceptible with a non-specific symptomatic presentation; victims can become sick or die before realizing they are exposed. However, CO poisoning related deaths are preventable.

CO poisoning causes approximately 50,000 people to visit the emergency department per year [2]. Of these, unintentional, non-fire related (UNFR) CO poisonings cause an estimated 21,000 people to visit an emergency department each year and result in hospitalization for more than 2300 [3]. Many CO poisoning cases occur in the home [4]. The most common sources of CO poisonings in homes are the use of gasoline-powered engines, such as electric generators, and malfunctioning heating and cooking appliances [1].

Several factors have affected CO poisoning death rates. Engineering innovations that decrease the amount of CO released from a source have been successful in reducing deaths from CO-poisoning. From 1968-1999, CO poisoning deaths declined due to advances such as the installation of catalytic converters in motor vehicles and the enforcement of standards set by the 1970 Clean Air Act [6,7]. Conversely, previous studies have shown that circumstances that lead to greater use of CO-emitting sources, such as winter storms, increase the number of CO poisoning deaths. Loss of electric power and increased cold weather during winter storms or disasters promotes an increased use of gasoline-powered generators in unventilated areas and indoor use of alternative heating sources, such as charcoal grills, consequently increasing the number of deaths [4,8–12].

☆ Presentation of this material: Council of State and Territorial Epidemiology, June 2014.
☆☆ Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

* Corresponding author. Air Pollution and Respiratory Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, MS F-58, Chamblee, GA 30341. Tel.: +1 770 488 3384; fax: +1 770 488 1540.
E-mail address: ddq0@cdc.gov (K. Sircar).

http://dx.doi.org/10.1016/j.ajem.2015.05.002
0735-6757/Published by Elsevier Inc.

Studies have postulated that interventions such as the installation of CO alarms can also reduce the number of deaths, possibly by half [13]. However, although many states have laws requiring CO alarms in new construction homes, older houses may not have a unit installed. Past studies have noted only 30% of households use CO alarms [14]. Even when homes have CO alarms, residents must remember to change batteries in the units regularly for them to work properly.

Although both unintentional and suicide related CO poisonings are preventable, public health intervention strategies differ. Interventions to prevent suicide-related poisonings focus on the sources of suicidal thoughts, while interventions to prevent unintentional poisonings focus on the source of the CO. For example, in unintentional fire-related CO poisoning, the fire is the source of the CO and therefore, fire prevention education and the use of flame retardant material are the focus. Unlike fire-related CO poisonings, UNFR CO poisoning victims do not sense the presence of a poisonous gas unless a CO alarm alerts them. Outreach and education for UNFR CO poisoning can range from increasing the use of CO alarms to educating consumers on the proper use of and care for related equipment and early sign and symptoms of CO poisoning. This analysis focuses on UNFR CO poisoning.

The objective of this study is to more comprehensively characterize the burden of CO poisoning-related mortality in the U.S and to characterize the populations most at-risk. Understanding the factors associated to UNFR CO poisoning death is a necessary component in the burden of both fatal and non-fatal CO poisoning cases and therefore a critical part for successful public health planning and prevention efforts.

2. Methods

To identify fatalities from CO poisoning, we used mortality data for multiple causes of death in the United States from the National Center for Health Statistic's National Vital Statistics System for the years 1999 through 2012. The dataset for this period is a compilation of all death certificate data without any personal identifiers. Fatalities were limited to those who resided and died in the 50 states and the District of Columbia.

We calculated the frequency of death due to non-medicinal poisonings listed on the death record and defined by *International Classification of Diseases, Tenth Revision* (*ICD-10*) codes T51–T65, "Toxic effects of substances chiefly non-medicinal as to source."

Table 1 presents the definitions for the CO poisoning deaths. T58, toxic effect of CO, can only be a contributory cause of death and not an underlying cause. Therefore, we used code X47 (accidental poisoning by exposure to gases and vapors) to denote poisoning as either an underlying or contributory cause [15]. The manner of death, along with the *ICD-10* code, distinguishes unintentional deaths ("accidental") from suicides ("suicides" or "self-harm"). We calculated annual crude rates for suicides, UNFR, and unintentional fire and vehicular-related CO poisoning deaths.

We adjusted death rates (DRs) for age using the direct standardization method and the US standard age population for year 2000 [16]. Denominator data for calculated rates came from the US Census population with bridged-race census counts or intercensal or postcensal estimates of the US resident population for July 1, 1999–July 1, 2012. For years 2000 and 2010, we used the census population count, and for all other years (1999, 2001–2009, 2011–2012) we used the intercensal or postcensal estimates [17]. We calculated all annual rates in units of deaths per one million persons (deaths per million); we did not present rates based on 10 or fewer deaths.

We stratified age-adjusted UNFR CO poisoning DRs by sex, race/ethnicity, educational attainment, marital status, urban/rural county of death classification, state, region, and year of death. For educational attainment analysis, we limited the population to persons 18 years and older and for marital status analysis, we limited the population to persons 15 years and older. Those categorized as "Widowed," "Never married, single," and "Divorced" were considered not married. In addition, we calculated age stratified rates and analyzed the average number of deaths per day by season, month, and day of the week. Finally, we computed frequencies for place of death and place of CO exposure.

We calculated 95 percent confidence intervals (95% CI) using the gamma method [18] and conducted analyses using SAS software (version 9.3; SAS Institute, Inc., Cary, NC). To determine if there was a statistical difference in the average number of deaths per day of the week, we used Poisson regressions using an alpha of 0.05.

3. Results

Among US residents in the 50 states and the District of Columbia, 34,215 CO poisoning deaths (*ICD-10* code: T58) occurred from 1999 to 2012. CO poisoning is the second most frequent poisoning listed on death certificates (Table 2).

The annual average age-adjusted UNFR CO poisoning DR for the study period (1999-2012) was 1.46 deaths per million (Table 3). Age-adjusted DRs were the highest for males (2.28 deaths per million) and non-Hispanic blacks (1.74 deaths per million). By age group, DRs were highest for those aged 85 years or greater (6.00 deaths per million) and lowest for those aged 5 to 14 years (0.25 deaths per million). Among decedents 18 years and older, 66% had a high school education or less. Finally, in 65% of the cases, UNFR CO decedents were not married (Table 3).

Forty-nine states had a sufficient number of deaths to permit calculation of age-adjusted death rates by state (Fig. 1). The Western region had the highest DR (2.05 deaths per million [95% CI: 1.96, 2.15]) and the Northeast had the lowest DR (0.91 deaths per million [95% CI: 0.85, 0.98]). The three states with the highest age-adjusted UNFR CO poisoning DR were Wyoming (5.14 deaths per million [95% CI: 3.62, 7.08]), Montana (3.66 deaths per million [95% CI: 2.70, 4.84]), and Alaska (3.77 deaths per million [95% CI: 2.66, 5.18]) (Fig. 1). Among States with more than 10 deaths, the lowest age-adjusted DRs per million persons were Massachusetts (0.49 deaths per million [95% CI: 0.36, 0.65]), New Jersey (0.82 deaths per million [95% CI: 0.67, 0.99]) and California (0.68 deaths per million [95% CI: 0.60, 0.75]). Further geographic analysis revealed that age-adjusted rates of UNFR CO deaths were higher in rural counties (2.28 deaths per million [95% CI: 2.18, 2.38]) than in urban counties (1.24 deaths per million [95%CI: 1.20, 1.27]) (Table 4).

Over half of the fatalities (54%, n = 3341) occurred in the decedent's home (Table 4), rather than in a medical center (18%, n = 1104. (Table 4) In 3744 (61%) of the deaths, the place of CO exposure was the home. In 549 (8%) of CO fatalities, exposure occurred in trade and service areas; 118 (1%) occurred in streets and highways, and 58 (1%) occurred in industrial and construction areas. Three percent (n = 193) of deaths were reported to be related to occupation.

Table 1
Definitions for UNFR, unintentional fire and vehicular and suicide carbon monoxide related death. Each death definition combines a Manner of Death code and an *ICD-10* code

	ICD-10 codes (either underlying or contributory cause)
UNFR	T58 & X47 Exclude: X00-X09, X76, X97, Y26, and Y17
Unintentional vehicular	T58& at least one from V01 to V99
Unintentional fire	T58 & at least one from X00-X09
Suicide	T58 & least one from X60 to X84

Table 2
Frequency of poisonings (Toxic effects of substances chiefly non-medicinal as to source) on the death certificates, 1999 to 2010

Poisons	Number of deaths	CO poisoning
Toxic effects of alcohol (*ICD-10* code: T51)	77,082	704 (0.9%)
Toxic effects of CO poisoning (*ICD-10* code: T58)	34,215	
Smoke inhalation excluding tobacco smoke (*ICD-10* code: T598)	34,037	5897 (17%)