U.S. Mortality Due to Carbon Monoxide Poisoning, 1999–2014

Accidental and Intentional Deaths

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Abstract

Rationale: Carbon monoxide (CO) poisoning accounts for hundreds of deaths and thousands of emergency department visits in the United States annually. Development of initiatives to reduce CO mortality through poisoning prevention requires a comprehensive understanding of the condition.

Objectives: To describe U.S. mortality from 1999 to 2014 due to CO poisoning from all sources except fires, to examine the epidemiology of accidental and intentional exposures, and to identify trends.

Methods: The CDC WONDER database was used to extract and analyze data from the CDC's Multiple Cause of Death 1999–2014 file. The file contains mortality data derived from all death certificates filed in the United States.

Measurements and Main Results: Information on deaths, crude death rate, age-adjusted death rate, intent of exposure, and characteristics of exposures from CO poisoning was extracted. Total deaths by CO poisoning decreased from 1,967 in 1999 to 1,319 in 2014 ($P < 0.001$). Crude and adjusted death rates fell accordingly. Accidental poisoning accounted for 13% fewer deaths per year in 2014 than in 1999 ($P < 0.001$). The number of intentional deaths by CO poisoning decreased by 47% over the same period ($P < 0.001$). The rate of decline in combined adjusted death rates from 1999 to 2014 in the 19 states that required residential CO alarms by 2010 was not different from that for the 31 states that did not require residential alarms ($P = 0.982$).

Conclusions: Numbers of deaths and death rates, both accidental and intentional, due to CO poisoning significantly declined in the United States from 1999 to 2014. Continued public education about CO toxicity should be emphasized. Additional study is needed to demonstrate the efficacy of residential CO alarms.

Keywords: carbon monoxide; poisoning; epidemiology; suicide; prevention

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Carbon monoxide (CO) poisoning accounts for hundreds of deaths and thousands of emergency department visits in the United States annually (1–3). Accidental exposures account for the majority of nonfatal poisonings (4), and intentional exposures account for the majority of deaths (1). Accidental CO poisoning is estimated to result in societal costs of over $1 billion annually in direct hospital costs and lost earnings (5).

The incidence of accidental and intentional CO poisoning may be impacted by public education, consumer product warning labels, residential CO alarms, and engineering advances minimizing CO emissions (6, 7). Efforts to reduce CO mortality require a comprehensive understanding of the condition. Studies with a national perspective are typically limited to a subset of the CO-poisoned population. Examples of constraints include poisoning intent (1, 3, 7), CO source (3), case identification method (8), entry location to the medical system (2, 3), and treatment used (4, 9). Because data collection methods differ between studies, subsets cannot necessarily be combined to gain a national perspective.

This report describes U.S. CO poisoning mortality from 1999 to 2014, examines the epidemiology of accidental and intentional deaths, identifies trends, and offers possible explanations for them. A comprehensive description of fatal CO poisoning in the United States will be helpful for planning, financing, developing, and implementing future prevention programs.

Methods

Annual U.S. data on number of deaths, crude death rate (CDR), age-adjusted death rate (ADR), exposure intent, and exposure characteristics (location by state, age group, sex, race, and ethnicity) due to CO poisoning were obtained using the CDC's WONDER database (10). WONDER is an open access online search system offered by the CDC to disseminate public health data.

The Multiple Cause of Death 1999–2014 file was used (11). It contains mortality data drawn from all death certificates filed in the United States. States provide coded data from death certificates to the National Center for Health Statistics, or coding is done by the National Center for Health Statistics using copies of state death certificates. Coding is performed by using a standardized method (12). Underlying and multiple causes of death are indexed by International Classification of Diseases, 10th Revision (ICD-10), codes for 113 selected causes of death, injury causes, and drug- and/or alcohol-induced causes of death. Each death certificate record contains a single underlying cause of death (UCD), up to 20 additional multiple causes, and demographic data (10).

CDC WONDER calculates death rates using population estimates from the U.S. Census Bureau (10). For confidentiality reasons, the system suppresses subnational data representing fewer than 10 persons. Rates are labeled "unreliable" when the death count in a category is fewer than 20.

CO poisoning deaths were identified using UCD terms "all causes of death," "accidental," or "suicide" plus "poisoning," then ICD-10 code T58 (Toxic effect of carbon monoxide) plus code X47 (Accidental poisoning by and exposure to other gases and vapors) or codes T58 and X67 (Intentional self-poisoning by and exposure to other gases and vapors) for multiple cause of death. Self-poisoning deaths of all types were identified using codes T36–T50 (Poisoning by drugs, medicaments, and biological substances) or T51–T65 (Toxic effects of substances chiefly nonmedical as to source), in combination with codes X60–X84 (Intentional self-harm). Cases of suicide of all forms were identified using UCD Injury Intent = Suicide. Codes related to fires were not included in this analysis. State requirements for residential CO alarms were obtained from the National Conference of State Legislators (13) and personal online reviews of state laws and codes.

Data were analyzed using descriptive statistics; logistic regression was used to evaluate trends; and covariance analysis was performed to compare slopes of linear regression lines. Death rates are followed by 95% confidence intervals. All crude and age-adjusted rates quoted have 95% confidence intervals not overlapping zero.

Results

From 1999 to 2014, there were a total of 24,890 CO poisoning deaths in the United States (6,653 accidental and 18,231 intentional), averaging 1,555 per year. A small number of homicidal CO poisonings or deaths of undetermined intent were excluded. Over this time, CO death numbers decreased significantly, from 1,874 in 1999 to 1,245 in 2014 ($P < 0.001$) (Table 1). Accidental and intentional deaths both decreased. Accidental poisoning accounted for approximately 50 fewer annual deaths in 2014 than in 1999 ($P < 0.001$), and intentional deaths decreased to an average of approximately 700 fewer per year ($P < 0.001$) (Figure 1). Crude and age-adjusted death rates fell accordingly.

Of the accidental deaths, 74% were in males (Table 2). The age group 45–54 years accounted for the greatest number of accidental deaths. White individuals accounted for 83% of accidental deaths. Hispanic or Latino origin was identified in 11% of the total. The elderly had the highest accidental death rates. Death rates for black and white individuals were similar.

Males accounted for 78% of intentional CO deaths (Table 2). Those aged 45–54 years had the highest incidence and CDR for intentional deaths. White individuals accounted for 96% of intentional deaths. Hispanic or Latino origin was identified in 3% of all intentional deaths. Deaths, ADR, and rank are listed for accidental and intentional poisoning by state in Table 3.

Table 1. Annual U.S. deaths, crude death rates per 100,000, and age-adjusted death rates per 100,000 for accidental and intentional carbon monoxide poisoning, and carbon monoxide poisoning of all types, from 1999 to 2014

	All			Accidental			Intentional		
	Deaths	**CDR**	**ADR (95% CI)**	**Deaths**	**CDR**	**ADR (95% CI)**	**Deaths**	**CDR**	**ADR (95% CI)**
1999	1,874	0.67	0.67 (0.64–0.70)	388	0.14	0.14 (0.12–0.15)	1,486	0.53	0.54 (0.51–0.56)
2000	1,826	0.65	0.65 (0.62–0.68)	436	0.15	0.16 (0.14–0.17)	1,390	0.49	0.50 (0.48–0.53)
2001	1,782	0.63	0.63 (0.60–0.66)	395	0.14	0.13 (0.12–0.14)	1,387	0.49	0.47 (0.45–0.50)
2002	1,798	0.63	0.62 (0.59–0.65)	441	0.15	0.14 (0.13–0.15)	1,357	0.47	0.47 (0.44–0.49)
2003	1,761	0.61	0.60 (0.57–0.63)	454	0.16	0.14 (0.13–0.16)	1,306	0.45	0.45 (0.42–0.47)
2004	1,698	0.58	056 (0.53–0.59)	418	0.14	0.15 (0.13–0.16)	1,279	0.44	0.45 (0.43–0.48)
2005	1,702	0.58	0.57 (0.54–0.60)	485	0.16	0.14 (0.13–0.15)	1,217	0.41	0.42 (0.40–0.44)
2006	1,661	0.56	0.53 (0.51–0.56)	440	0.15	0.14 (0.13–0.16)	1,220	0.41	0.40 (0.38–0.42)
2007	1,663	0.55	0.52 (0.50–0.55)	442	0.15	0.13 (0.12–0.15)	1,220	0.41	0.39 (0.37–0.41)
2008	1,537	0.51	0.50 (0.47–0.52)	455	0.15	0.14 (0.13–0.15)	1,104	0.36	0.34 (0.32–0.36)
2009	1,430	0.47	0.46 (0.43–0.48)	440	0.14	0.14 (0.13–0.16)	1,081	0.32	0.31 (0.30–0.33)
2010	1,260	0.41	0.39 (0.37–0.41)	382	0.12	0.12 (0.11–0.13)	989	0.28	0.28 (0.26–0.30)
2011	1,289	0.41	0.38 (0.36–0.41)	421	0.14	0.12 (0.11–0.13)	878	0.28	0.29 (0.27–0.30)
2012	1,193	0.38	0.36 (0.34–0.38)	332	0.11	0.11 (0.10–0.12)	868	0.27	0.26 (0.24–0.28)
2013	1,171	0.37	0.35 (0.33–0.38)	340	0.11	0.09 (0.08–0.10)	861	0.26	0.25 (0.23–0.27)
2014	1,245	0.39	0.37 (0.35–0.39)	384	0.12	0.11 (0.10–0.12)	831	0.27	0.27 (0.26–0.29)
Total	24,890	0.52	0.49 (0.49–0.50)	6,653	0.14	0.14 (0.14–0.14)	18,231	0.38	0.36 (0.35–0.36)

Definition of abbreviations: ADR = age-adjusted death rate; CDR = crude death rate; CI = confidence interval.

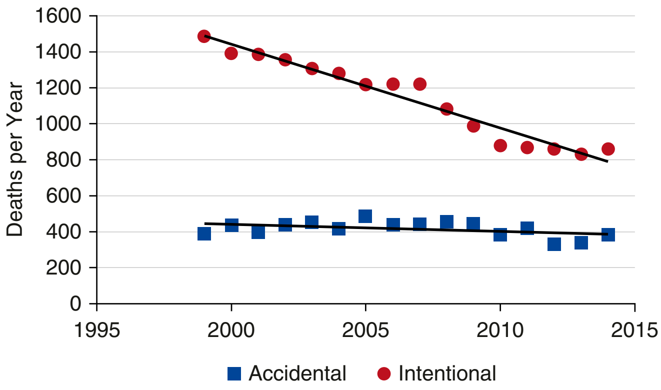

Figure 1. Annual U.S. deaths due to carbon monoxide poisoning. Linear regression lines for accidental ($y = -3.92 \times +8{,}274$; $r = 0.99$; $P < 0.001$) and intentional ($y = -46.59 \times +94{,}628$; $r = 0.99$; $P < 0.001$) poisoning are shown.

As of January 1, 2010, 19 states, representing 41% of the U.S. population, had enacted regulations requiring CO alarms in at least one major category of residence (11, 13). When combined age-adjusted accidental death rates from 1999 to 2014 for the states with CO alarm regulations by 2010 are compared with rates in those states without such regulations (Figure 2), there is no significant difference in the rate of decline ($P = 0.980$).

Age-adjusted death rates for self-poisoning of all types increased from 1999 to 2014 ($P < 0.001$), with deaths increasing from 4,888 with ADR of 1.75 (1.70–1.80) to 6,802 with ADR of 2.02 (1.97–2.07). Mortality due to suicide of all types also rose ($P < 0.001$), with 29,199 deaths and ADR of 10.47 (10.35–10.59) increasing to 42,773 with ADR of 12.96 (12.84–13.09).

Table 2. Total U.S. deaths and crude death rates per 100,000 due to carbon monoxide poisoning for the period 1999–2014, by demographic group and divided into accidental and intentional poisoning

	Accidental		Intentional	
	Deaths	**CDR**	**Deaths**	**CDR**
Sex				
Female	1,728	0.07	4,005	0.16
Male	4,925	0.21	14,226	0.60
Age				
<1 yr	24	0.04		
1–4 yr	75	0.03		
5–14 yr	156	0.02	5	Unreliable
15–24 yr	603	0.09	998	0.15
25–34 yr	787	0.12	2,479	0.38
35–44 yr	1,116	0.16	4,426	0.65
45–54 yr	1,243	0.18	5,016	0.74
55–64 yr	939	0.18	2,816	0.56
65–74 yr	608	0.18	1,070	0.32
75–84 yr	659	0.32	911	0.44
85+ yr	443	0.55	465	0.58
Race				
American Indian or Alaska Native	76	0.13	72	0.12
Asian or Pacific Islander	149	0.06	258	0.11
Black or African American	937	0.15	470	0.07
White	5,491	0.14	17,431	0.45
Hispanic or Latino				
Yes	719	0.10	478	0.07
No	5,911	0.15	17,697	0.43

Definition of abbreviations: CDR = crude death rate.

Discussion

CO poisoning deaths steadily declined in the United States from 1999 to 2014. This occurred with both accidental and intentional fatalities. Previous studies have examined selected similar variables, and this report extends their findings.

In 1991, Cobb and Etzel published an analysis of U.S. CO-related deaths from 1979 to 1988 (14). Their study was focused on unintentional poisoning mortality, and they reported a steady decline, with deaths decreasing from 1,513 in 1979 to 878 in 1988. Death data coding at that time included CO source, with motor vehicles responsible for 57% of unintentional deaths. Higher death rates were seen among black individuals; the elderly; in winter months; and in cold, high-altitude states.

In a 2002 analysis of U.S. non–fire-related CO deaths from 1968 to 1988, Mott and coworkers concentrated on those CO deaths caused by motor vehicles (6). Annual accidental CO deaths from all sources decreased from 1,417 in 1968 to 491 in 1998. Intentional CO deaths decreased from 2,371 in 1968 to 1,747 in 1998. Motor vehicles were associated with 71% of deaths. Mott and colleagues estimated 11,700 CO-related deaths were prevented by 1998, accompanying a 76% decrease in motor vehicle CO emissions after the 1975 introduction of the catalytic converter.

In 2007, the CDC reported information on unintentional, non–fire-related deaths due to CO from 1999 to 2004 (1). Of 16,400 total deaths, 2,631 were unintentional and not fire related. CO poisoning death rates in this group were higher among males and those over 65 years of age. Rates were similar among black and white individuals. The states with the highest accidental mortality rates were Nebraska and Montana, while the lowest rates were in California and New York.

In the present study, accidental and intentional CO poisoning mortality continued to decline (Figure 1). Regression analysis of the data demonstrates a 13% decrease in accidental CO deaths over 16 years. This is in contrast to the 65% decrease in accidental deaths estimated by Mott and colleagues for the preceding 31 years (6).

Table 3. State-specific data on accidental and intentional carbon monoxide–related deaths from 1999–2014, including number of deaths, age-adjusted death rates per 100,000, and ranking of age-adjusted death rates by state

	Accidental CO Poisoning			Intentional CO Poisoning			All Suicides
	Deaths	ADR	Rank	Deaths	ADR	Rank	Rank
Alabama	119	0.16	25	191	0.27	39	24
Alaska	40	0.37	2	48	0.42	27	1
Arizona	114	0.12	35	439	0.47	22	9
Arkansas	83	0.18	19	147	0.31	35	14
California	352	0.06	45	1,148	0.21	45	43
Colorado	156	0.20	15	731	0.94	2	8
Connecticut	64	0.11	37	279	0.47	23	47
Delaware	16	Unreliable	—	48	0.34	31	35
District of Columbia		Suppressed			Suppressed		51
Florida	385	0.13	30	1,333	0.44	25	22
Georgia	147	0.10	40	426	0.30	36	37
Hawaii		Suppressed	—	48	0.21	46	40
Idaho	60	0.26	6	169	0.75	7	7
Illinois	391	0.19	17	949	0.45	24	45
Indiana	224	0.22	10	599	0.58	13	25
Iowa	112	0.23	9	384	0.78	4	32
Kansas	83	0.19	18	246	0.55	16	20
Kentucky	148	0.22	11	201	0.32	34	15
Louisiana	80	0.11	39	86	0.14	50	31
Maine	33	0.16	26	84	0.38	29	23
Maryland	115	0.13	31	241	0.26	42	46
Massachusetts	56	0.05	46	292	0.28	37	48
Michigan	270	0.17	21	831	0.52	18	36
Minnesota	179	0.22	12	550	0.67	10	42
Mississippi	60	0.13	32	80	0.17	48	26
Missouri	225	0.24	8	454	0.49	21	19
Montana	56	0.37	3	153	1.01	1	3
Nebraska	86	0.30	5	195	0.72	8	41
Nevada	69	0.17	22	228	0.58	14	5
New Hampshire	27	0.13	33	126	0.58	15	27
New Jersey	118	0.08	44	401	0.28	38	50
New Mexico	78	0.25	7	154	0.51	19	4
New York	287	0.09	42	564	0.17	49	49
North Carolina	180	0.13	34	501	0.33	32	30
North Dakota	33	0.31	4	77	0.76	6	18
Ohio	321	0.17	23	982	0.52	18	38
Oklahoma	100	0.17	24	220	0.39	28	11
Oregon	71	0.12	36	322	0.51	20	10
Pennsylvania	432	0.22	13	910	0.43	26	34
Rhode Island	17	Unreliable	—	63	0.36	30	44
South Carolina	82	0.12	37	183	0.26	43	28
South Dakota	28	0.22	14	87	0.70	9	12
Tennessee	149	0.15	28	277	0.27	40	17
Texas	390	0.10	41	752	0.21	47	39
Utah	65	0.16	27	292	0.78	5	6
Vermont	19	Unreliable		35	0.33	33	16
Virginia	105	0.09	43	328	0.25	44	33
Washington	154	0.15	29	655	0.61	11	21
West Virginia	52	0.18	20	84	0.27	41	13
Wisconsin	182	0.20	16	557	0.61	12	29
Wyoming	38	0.44	1	75	0.88	3	2

Definition of abbreviations: ADR = age-adjusted death rate; CO = carbon monoxide.
Ranking of states by ADR for suicide of all types over the same time period is provided for comparison. The CDC WONDER database suppresses subnational data representing fewer than 10 persons for reasons of confidentiality and labels rates as unreliable when the death count in a category is less than 20.

Accidental CO Poisoning Deaths

The continued decline in accidental deaths is likely related in part to ongoing reduction in CO production by motor vehicles (15). Automobiles manufactured prior to 1975 continue to disappear from the road, and emissions engineering continues to advance, both contributing to reduction in CO production. The influence of motor vehicles on accidental poisoning deaths should level off when further reduction in CO emissions becomes too difficult or expensive. That may be happening now. Mott and coworkers attributed 48% of accidental CO deaths in 1998 to motor

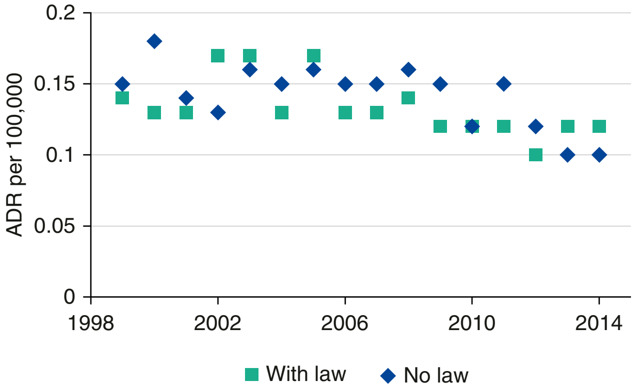

Figure 2. Age-adjusted death rates (ADR) for accidental carbon monoxide poisoning from 1999–2014 in the group of 19 states with laws requiring residential carbon monoxide alarms by 2010 and the 31 states without such laws (*see* text for states included in each group).

vehicles. Unfortunately, ICD-10 coding of death certificates, which started in 1999, does not identify CO sources. However, a recent 3-year national surveillance study of nonfatal CO poisonings showed that only 13% of 1,604 accidental cases were related to motor vehicles, supporting the observation that the rate of reduction in accidental deaths is slowing (4).

In 2007, CDC authors recommended continuing tracking of accidental CO mortality to assess the effect of increasing use of residential CO alarms (1). As of January 1, 2016, 30 states had enacted regulations requiring installation of residential CO alarms in at least one category of domicile (13). These laws generally require immediate alarm installation only in new-construction and rental units. For existing single-family homes, alarm installation is usually required when a home is sold or a permit is issued for remodeling or repair. The penetration of CO alarms into the single-family home sector depends upon home turnover rate and the effectiveness of public education promoting alarms.

As of January 1, 2010, 19 states required residential CO alarms (13). At least 5 years of accidental mortality data following regulation enactment is therefore available for those states. Figure 2 compares the adjusted death rates for states that required CO alarms by 2010 with those that did not. The rate of decrease in ADR is similar in both groups, with no evidence from these data that alarm legislation has reduced mortality.

Despite this finding, in light of the extremely positive experience with smoke alarms (16), properly installed and maintained CO alarms are probably effective at reducing mortality, and the policies should not be abandoned. It should be recognized that proper maintenance includes periodic device replacement, as the CO sensors have limited lifespans (17). Failure to properly maintain or replace CO alarms could result in a false sense of security, although alarms manufactured since 2009 have been required to emit an end-of-life signal to prompt timely replacement (17).

More information is needed on alarm prevalence in homes after enactment of legislation. If the rate of installation is low, 5 years may be insufficient to expect a recognizable effect. Alternatively, death rates could be similar because residents of states not requiring alarms may be installing them at a rate similar to rates in states with requirements because of public education about CO poisoning.

In addition, state requirements differ (12). Some require alarms only in rental units, some only in new construction, and some exclude residences without fuel-burning appliances or an attached garage. If standards are identified with higher accidental CO death rates once alarms are in widespread use, regulations may need revision. More research regarding CO alarms is needed.

Intentional CO Poisoning Deaths

In the study by Mott and coworkers, accidental CO mortality declined more than intentional mortality from 1968 to 1998 (6). The converse is true for the period from 1999 to 2014, during which the decrease in intentional deaths was several-fold that of accidental deaths. There were 1,486 intentional CO deaths in 1999 and 861 in 2014.

The reasons for such a dramatic drop in intentional deaths are not entirely clear. It is not the result of declining overall suicide mortality, as intentional deaths of all types have increased steadily since 1999. Likewise, the death rate due to self-poisoning of all types increased from 1999 to 2014.

The major reason for declining intentional CO deaths may be the U.S. Clean Air Act of 1970 (15), which contains the regulations responsible for reducing vehicle CO emissions. Interestingly, both fatal and nonfatal intentional CO poisoning have been correlated with the reduction in motor vehicle CO emissions that has occurred (6, 7). CO emissions from late-model cars are felt to be so low that committing suicide with such a car requires running the engine in a tightly sealed enclosure for a very long time (7, 18). Both engine efficiency and catalytic converter effectiveness will decrease when ambient oxygen is eventually consumed and the environment becomes hypoxic, leading to increased production and decreased clearance of CO. It is also possible to attempt suicide by CO poisoning but die a hypoxic death if the sealed space is the passenger compartment and exhaust gas containing high levels of carbon dioxide with low levels of oxygen and CO are routed inside (19). The latter has been reported only rarely.

Patients treated for nonfatal intentional CO poisoning from motor vehicles are presenting with evidence of less severe exposures and are decreasing in numbers (7). Presumably, those attempting suicide are not seeking a method that requires several hours. Some books and websites giving advice on successful suicide recommend against using CO from a motor vehicle anymore, especially in countries with strict emissions controls such as the United States (7). The intentional CO death rate is likely falling rapidly because the method is being used less often and those who attempt suicide with motor vehicle CO may be less successful.

State-by-State CO Deaths

Northern latitude and high-altitude states tend to have the highest death rates from accidental CO poisoning (e.g., Wyoming, Alaska, Montana) (Table 3). This is similar to prior studies and felt to be driven largely by wintertime home-heating incidents (1, 14). However, states with the lowest accidental ADRs (e.g., Massachusetts, California, New Jersey) are not necessarily those with the warmest climates. Their accidental death rates are probably low because of poisoning prevention programs such as stringent vehicle emissions controls and aggressive public education. While the Environmental Protection Agency mandates emissions standards, states may apply for waivers to require more stringent standards. California enacted stricter emissions regulations in 2002 in its "Clean Cars" initiative, and 13 other states followed (20). Of the 5 states with the lowest accidental ADR, 4 are among that group of 14.

States with high intentional CO ADRs (Montana, Colorado, and Wyoming) also have colder winter climates, as do states with the highest death rates from suicide of all types (Alaska, Wyoming, and Montana) (Table 3). The association of cold climate with high death rates in all three categories raises the possibility that those attempting suicide in colder climates choose CO poisoning as a method because more CO sources are available.

Limitations

This study's major limitation relates to death certificate coding, specifically the inability to identify the CO sources from certificates coded with ICD-10 codes since 1999. If information about CO source were available, it would be possible to test some of the hypotheses put forward above. Instead, it will be necessary to glean information regarding the relative prevalence of CO sources from emergency department surveillance systems (3), nationwide poison control center data (8), and reports of large series of patients (4).

In addition, this study excluded fire-related CO poisoning deaths due to the inherent difficulties those patients present with assignment of a primary cause of death. While they could have CO poisoning, they could also have, for example, smoke inhalation injury with respiratory failure or thermal burns with sepsis. Excluding them in the present study allowed comparison of results with the findings of prior studies, as they have also excluded fire-related deaths.

Future Opportunities

Efforts to reduce mortality due to accidental CO poisoning have obviously been successful, extending perhaps inadvertently also to intentional CO mortality. Accidental deaths in the United States have declined from approximately 1,400–1,500 in 1968 (6, 14) to around 350 in recent years. Coincident with this has been a drop in CO emitted by highway vehicles from 163 million tons in 1970 to 22 million tons in 2014, despite more vehicles on the road (21). When further lowering of CO emissions from motor vehicles becomes impractical, additional attention should be focused on other CO-producing engines associated with poisoning, such as electricity generators or boats (4, 22).

The potential value of residential CO alarms cannot be underestimated. They are a possible defense against furnace malfunctions, motor vehicles left running in attached garages, and even CO from an adjacent apartment in a multifamily dwelling. If their effectiveness is anywhere close to that of smoke alarms, they would be cost-effective (5). Now that so many states have enacted alarm legislation, more studies are needed to measure compliance with these regulations. If low, barriers to installation must be identified and resolved. Only when a high use rate has been achieved will it be possible to determine how effectively alarms impact accidental CO mortality.

Intentional CO deaths in the United States have decreased from 2,400 in 1968 (6) to about 900 per year currently. Most of that decline has occurred since 1989 and is felt to be due to decreased automobile CO emissions (6, 7). It is encouraging that intentional CO poisoning mortality continues to fall, but discouraging that mortality due to suicide of all forms continues to rise. Individuals who survive a CO suicide attempt have a poor long-term prognosis, typically dying due to a subsequently completed suicide (23). They should be followed closely following an unsuccessful suicide attempt.

Finally, public education is of vital importance. One example of education is warning labels. Due to concern that warnings on bags of charcoal briquettes were ineffective because the required warning was verbal and those poisoned did not speak English (24), the U.S. Consumer Product Safety Commission mandated label revision in November 1997 (25). A nonverbal pictogram was added, and the explanation of the risk of indoor use was clarified.

The U.S. Consumer Product Safety Commission tracks injuries and deaths related to many products, including accidental CO poisoning from charcoal briquettes (26). The number of charcoal-related CO deaths in the United States decreased by more than 60% following introduction of the new label. From 1981 to 1997 there were an average of 25.2 annual deaths from charcoal, and from 1998 to 2011 there were an average of 9.6 deaths annually (26). Public education can be powerful if at-risk populations can be identified and targeted. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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