Review of Unintentional Non-Fire-Related Carbon Monoxide Poisoning Morbidity and Mortality in Florida, 1999–2007

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SYNOPSIS

Objective. Previous Florida evaluations of carbon monoxide (CO) poisoning have been disaster focused. The majority of prevention messages and risk-factor identification efforts have revolved around hurricane season (June–November). We evaluated the prevalence, risk factors, and causes of CO poisoning within Florida throughout the year to produce a more complete presentation of the burden of CO poisoning.

Methods. We obtained data from death certificates, hospital discharge records, and emergency department records. We limited our analysis to unintentional poisonings, calculating rates for age, gender, race, and ethnicity, and reviewing poisoning chronology, location, and exposure situation.

Results. From 1999 to 2007, 493 people were hospitalized, and 230 individuals died as a result of non-fire-related CO poisoning. From 2005 to 2007, 781 people visited emergency departments for non-fire-related CO poisoning. Rates of severe poisoning resulting in hospitalization or death were highest among the elderly (0.56 visits and 0.63 deaths per 100,000 Floridians). Acute poisoning rates were highest among people 25–34 years of age (2.48 visits per 100,000 Floridians). Poisonings were primarily due to motor vehicle exhaust (21%–69%) and generator exposure (12%–33%), and the majority (50%–70%) occurred within the home. A large number of poisonings (25%–29%) occurred during the winter months, outside of hurricane season.

Conclusion. The findings of this study indicate a need for additional prevention strategies in conjunction with current activities to more effectively reduce the number of CO poisonings in Florida. Prevention activities should be conducted year-round, and additional strategies should include public awareness of the hazards of motor vehicle exhaust.

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Unintentional, non-fire-related (UNFR) carbon monoxide (CO) poisoning is a very real public health concern. From 2004 to 2006, 20,636 individuals per year sought medical care from U.S. emergency departments (EDs) for UNFR CO poisoning.[1] In addition, from 1999 to 2004, there were 439 CO-related fatalities per year in the U.S.[2] The health risks associated with CO poisoning vary with concentration and exposure; however, children, pregnant women, and individuals with preexisting medical conditions, such as ischemic heart disease or chronic obstructive pulmonary disease, have a higher risk of a severe outcome.[3] Recent research has highlighted that even very small concentrations of CO may impact fetal development.[4] The symptoms of CO exposure are nonspecific and include headache, dizziness, nausea, and disorientation. These nonspecific symptoms may mimic other less serious conditions, leading individuals to delay seeking medical treatment.[5,6] Almost all UNFR CO poisoning cases are avoidable with the adoption of appropriate safety and prevention measures, including the proper installation, maintenance, and operation of fuel-burning devices in conjunction with the use of CO detectors.[7] Identification of risk behaviors and incorporation of these into meaningful targeted messages is needed to successfully reduce unintentional CO poisoning.

The Florida public health community has become increasingly active in CO poisoning prevention. In 2004, Florida was hit by an unprecedented four hurricanes within a two-month span, resulting in widespread long-term power outages. Widespread power outages also occurred during 2005 in the aftermath of three hurricanes. As a result of each of these large-scale disasters, generator-safety flyers and other safety messages were developed and utilized in a series of culturally sensitive interventions. In addition, enhanced surveillance for CO poisoning, using data from the Florida Poison Information Center Network (FPICN) and medical examiners' records, was initiated. This information was used to further target awareness campaigns.

Review of data for the 2004 and 2005 events provided the basis for the majority of the literature related to CO poisoning and exposure information within the state of Florida.[8–12] However, the Florida burden of unintentional CO poisoning in the absence of a disaster has not been evaluated. A number of national studies and reviews have been conducted that examine the prevalence, risk factors, and causes of CO poisoning. These studies have indicated that while there are similarities in risk factors, regional differences do exist. We investigated the epidemiology of acute and severe CO poisoning in Florida, reviewing historical mortality and morbidity data, to continue to create targeted prevention strategies within the state, identify gaps in data collection, and explore the CO-poisoning burden in non-disaster years.

METHODS

We defined CO poisoning using the Council of State and Territorial Epidemiologists' (CSTE) definition of confirmed and probable exposure (Figure 1). We

Figure 1. CSTE definitions for confirmed and probable cases of CO poisoning, based on administrative data

ICD version	*Code*	*Definition*
ICD-9-CM		
Confirmed	986	Toxic effect of CO
	E868.3	Accidental CO poisoning from incomplete combustion of other domestic fuels
	E868.8	Accidental CO poisoning from other sources
	E868.9	Unspecified CO
	E952.1	Suicide and self-inflicted poisoning by CO
	E982.1	Poisoning by CO; undetermined whether accidental or purposely inflicted
Probable	E868.2	Accidental poisoning from motor vehicle exhaust
	E952.0	Suicide and self-inflicted poisoning by motor vehicle exhaust
	E982.0	Poisoning by motor vehicle exhaust; undetermined whether accidental or purposely inflicted
ICD-10		
Confirmed	T58	Toxic effect of CO

CSTE = Council of State and Territorial Epidemiologists

CO = carbon monoxide

ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification

ICD-10 = International Classification of Diseases, 10th Revision

identified CO-related morbidity using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes and CO-related mortality using the ICD, 10th Revision (ICD-10) codes.[13]

We obtained morbidity data from the Florida Agency for Health Care Administration (AHCA), which collects data on all patients treated in non-federal Florida hospitals or EDs. We included records if one or more of the CO-related ICD-9-CM codes were present in the primary or secondary diagnosis fields. We extracted specific information about location of injury and/or source of poisoning using ICD-9-CM external-cause-of-injury codes (e-codes). We extracted hospitalization data for 1999–2007. AHCA began collecting ED data in 2005; therefore, we present ED-related information for 2005–2007.

We obtained death certificate data for 1999–2007 from the Florida Department of Health Bureau of Vital Statistics database. We included records if the ICD-10 code T58 was listed as the cause of death or a contributing cause of death. We obtained specific information about location of death and source of exposure from variables on the death certificate. To avoid duplicate records, we excluded from the morbidity analysis individuals who died in the hospital or ED. Using hospitalization records, we excluded from the ED analysis individuals who were treated in the ED and then transferred to a short-term hospital. We calculated rates using annual demographic population estimates from the Florida Legislature's Office of Economic and Demographic Research. We calculated fatality rates as the number of CO deaths, divided by the sum of CO deaths and CO hospitalizations, multiplied by 100.

We identified extracted records for CO poisoning as intentional (suicide or homicide), unintentional (fire related or non-fire related), or undetermined due to not enough details (unknown) based on ICD-9-CM or ICD-10 coding categories (Figure 2). Within these categories, the following demographic information was summarized: age, gender, race (white, black, other, or unknown), and ethnicity (Hispanic, non-Hispanic, or unknown). Previous studies have shown that causal factors, exposures, and severity of CO poisoning vary by each of these demographic variables.[1,2,14,15]

We calculated crude, age-adjusted rates with 95% confidence intervals (CIs) for all demographic variables. We also calculated rate ratios (RRs). We used *p*-values from Pearson's Chi-square test and a comparison of 95% CIs to determine statistical significance.

RESULTS

From 2005 to 2007, 1,189 Florida residents were treated in the ED for CO poisoning. Twelve percent (n=139) of these ED visits were categorized as attempted suicide, and <1% (n=6) were categorized as homicide. UNFR CO poisoning accounted for the majority (66%, n=781) of ED visits. Unintentional fire-related CO poisoning accounted for only 2% (n=28) of ED visits, and unknown CO poisoning accounted for 20% (n=235) of ED visits.

From 1999 to 2007, 1,494 Florida residents were hospitalized with a diagnosis of CO poisoning. Of these hospitalizations, 40% (n=591) were categorized as attempted suicide and <1% (n=11) were categorized as homicide. The remaining CO poisoning hospitalizations in the period 1999–2007 were due to unintentional fire-related (10%, n=143), UNFR (33%, n=493), or unknown (17%, n=256) CO poisoning. During this same time period, 1,388 Florida residents died with CO listed as the cause of death or a contributing cause of death. Of these deaths, 62% (n=865) were due to suicide and 2% (n=24) were due to homicide. Most of the remaining 36% (n=499) of deaths were attributed to fire or to non-fire events in similar proportions (fire-related CO poisoning: 17%, n=242; UNFR CO poisoning: 17%, n=230). Unknown CO poisoning represented a small number of deaths (2%, n=27).

While unintentional CO poisoning is almost entirely preventable, the specific prevention strategies for UNFR vs. fire-related CO poisoning are distinctly different.[15] In this article, we focus on characterizing the mortality and morbidity of CO poisoning as measured through both ED visits and hospitalizations for CO poisoning of UNFR or unknown intent.

ED visits: 2005–2007

Demographics. Of the 1,016 individuals seen in EDs for CO poisoning from 2005 to 2007, we classified 1,011 as confirmed (as opposed to probable) using the CSTE case definition for CO poisoning. Seventy-seven percent (n=781) of these CO poisoning cases were UNFR, while 23% (n=235) were of unknown intent. Illness related to CO poisoning seen in EDs was fairly self-limiting, as 95% (n=743) of UNFR CO poisoning patients and 92% (n=217) of unknown CO poisoning patients were discharged to home or self-care.

White females comprised the majority of cases in each category (UNFR and unknown). Black people were more likely than white people to be treated for UNFR CO poisoning (RR=2.0, p<0.0001). Hispanic and non-Hispanic people had the same rate of ED

Figure 2. Codes and definitions used by the Florida Department of Public Health to categorize intent of CO poisoning as intentional (homicide or suicide) or unintentional (fire related, non-fire related, or undetermined)

ICD-9-CM	*Code*	*Definition*
Homicide	E960–E969	Homicide and injury purposely inflicted by other people
Suicide	E950–E959	Suicide and self-inflicted injury
Fire related	E890–E899	Accidents caused by fire and flames
Non-fire related	E800–E848	Transport accident
	E850–E858	Accidental poisoning by drugs, medicinal substances, and biologicals
	E860–E869	Accidental poisoning by other solid and liquid substances, gases, and vapors
	E880–E888	Accidental falls
	E900–E928	Unintentional injury other than e-codes for coding place or injury due to medical intervention
Undetermined due to not enough details	E980–E989	Injury undetermined, whether accidentally or purposely inflicted
	NA	All other e-codes not previously listed
	NA	Cases where e-code information was missing
ICD-10	*Code*	*Definition*
Homicide	X85–Y09	Assault
Suicide	X60–X84	Intentional self-harm
Fire related	X00–X09	Exposure to smoke, fire, and flames
Non-fire related	V01–V99	Transport accidents
	W00–W84	Other external cause of accidental injury
	X00–X59	Other external cause of accidental injury
	Y85	Sequelae of transport accidents
	Y86	Sequelae of other accidents
Undetermined due to not enough details	Y10–Y34	Event of undetermined intent[a]

[a]Notes on the death certificate allowed for identification and exclusion of cases that were fire related.

CO = carbon monoxide

ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification

NA = not applicable

ICD-10 = International Classification of Diseases, 10th Revision

visits for UNFR CO poisoning (RR=0.8, p=0.05) and unknown CO poisoning (RR=1.0, p=0.09). The highest rates of ED visits for UNFR CO poisoning occurred in adults 25–34 years of age (2.48 visits per 100,000 population) and 35–44 years of age (1.92 visits per 100,000 population). Among unknown CO poisonings, the highest rates were seen in those 35–44 years of age (0.66 visits per 100,000 population), followed by those 25–34 years of age (0.58 visits per 100,000 population). Further demographic information for UNFR and unknown CO poisoning patients is provided in Tables 1 and 2.

Exposure situation and cause. An e-code with information about the cause and situation of CO exposure was included in the ED data for the majority (91%, n=692) of all UNFR CO poisonings. Of these 692 records, 31% (n=217) of CO poisonings were from a known source not specified in the ICD-9-CM codes, such as generators, industrial kilns, and blast furnaces. In addition, 21% (n=147) of poisonings were from motor vehicle exhaust fumes. Only 17% (n=41) of unknown CO poisoning records had information on the cause and situation regarding poisoning, the majority (85%, n=35) of which were from motor vehicle exhaust fumes. There was no difference in exposure situation by race for either UNFR or unknown CO poisonings.

Place of exposure. The place associated with CO poisoning exposure (ICD-9-CM e-code E849) was not uniformly recorded. In ED records, only 27% (n=204) of UNFR CO poisoning records and 28% (n=65)

Table 1. Estimated annual number, percentage, and rate of Florida residents with nonfatal and fatal UNFR CO exposures, by selected characteristics: 1999–2007[a]

	ED visits (n=781)[b]				*Hospitalizations (n=493)*				*Fatalities (n=230)*				
Attribute	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	*Fatality rate[d]*
Age (in years)													
0–14	51.0	19.6	1.50	(1.26, 1.74)	6.6	12.0	0.20	(0.15, 0.26)	1.9	7.4	0.06	(0.03, 0.09)	22.4
15–24	37.3	14.3	1.57	(1.28, 1.86)	5.4	9.9	0.25	(0.18, 0.32)	2.2	8.7	0.10	(0.06, 0.15)	29.0
25–34	55.3	21.3	2.48	(2.10, 2.86)	3.7	6.7	0.17	(0.11, 0.23)	2.4	9.6	0.11	(0.07, 0.16)	40.0
35–44	49.3	19.0	1.92	(1.61, 2.23)	9.2	16.8	0.37	(0.29, 0.44)	3.6	13.9	0.14	(0.09, 0.19)	27.8
45–54	34.3	13.2	1.33	(1.07, 1.59)	9.8	17.8	0.42	(0.33, 0.51)	3.9	15.2	0.17	(0.11, 0.22)	28.5
55–64	15.0	5.8	0.72	(0.51, 0.92)	7.2	13.2	0.39	(0.30, 0.49)	2.7	10.4	0.14	(0.09, 0.20)	27.0
65–74	9.7	3.7	0.63	(0.40, 0.86)	4.9	8.9	0.33	(0.23, 0.42)	2.8	10.9	0.19	(0.11, 0.26)	36.2
75–84	6.3	2.4	0.54	(0.30, 0.78)	6.2	11.4	0.56	(0.42, 0.71)	3.7	14.3	0.33	(0.22, 0.45)	37.1
≥85	2.0	0.8	0.45	(0.09, 0.82)	1.8	3.2	0.46	(0.23, 0.68)	2.4	9.6	0.63	(0.37, 0.89)	57.9
Gender													
Male	125.3	48.1	1.39	(1.25, 1.53)	31.7	57.8	0.38	(0.33, 0.42)	16.2	63.5	0.19	(0.16, 0.22)	33.9
Female	135.0	51.9	1.44	(1.30, 1.58)	23.1	42.2	0.26	(0.23, 0.30)	9.3	36.5	0.11	(0.08, 0.13)	28.8
Race													
White	177.3	68.1	1.19	(1.09, 1.29)	40.3	73.6	0.29	(0.26, 0.32)	22.3	87.4	0.16	(0.14, 0.18)	35.6
Black	73.7	28.3	2.43	(2.11, 2.75)	12.3	22.5	0.45	(0.37, 0.53)	2.6	10.0	0.09	(0.06, 0.13)	17.2
Other	7.3	2.8	1.44	(0.84, 2.05)	1.4	2.6	0.33	(0.15, 0.51)	0.7	2.6	0.15	(0.03, 0.27)	31.6
Unknown	2.0	0.8	NC	NC	0.7	1.2	NC	NC	0.0	0.0	NC	NC	NC
Ethnicity													
Non-Hispanic	214.3	82.3	1.45	(1.34, 1.57)	46.0	83.9	0.33	(0.29, 0.36)	21.6	84.3	0.15	(0.13, 0.17)	31.9
Hispanic	44.0	16.9	1.20	(1.00, 1.41)	8.1	14.8	0.27	(0.20, 0.33)	4.0	15.6	0.13	(0.09, 0.17)	33.0
Unknown	2.0	0.8	NC	NC	0.7	1.2	NC	NC	0.0	0.0	NC	NC	NC
Total	260.3	100.0	1.42	(1.32, 1.51)	54.8	100.0	0.32	(0.29, 0.35)	25.6	100.0	0.15	(0.13, 0.17)	31.8

[a]Rates and 95% CIs were not calculated where the total number of cases was <4.

[b]ED visit data are for 2005–2007 only.

[c]Annual mean

[d]Number of CO deaths, divided by the sum of CO deaths and CO hospitalizations, multiplied by 100.

UNFR = unintentional non-fire related

CO = carbon monoxide

ED = emergency department

CI = confidence interval

NC = not calculated

Table 2. Estimated annual number, percentage, and rate of Florida residents with nonfatal and fatal unknown CO exposures, by selected characteristics: 1999–2007[a]

	ED visits (n=235)[b]				*Hospitalizations (n=256)*				*Fatalities (n=27)*				
Attribute	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	N[c]	*Percent*	*Rate/ 100,000 people*	*(95% CI)*	*Fatality rate[d]*
Age (in years)													
0–14	9.7	12.3	0.28	(0.18, 0.39)	1.9	6.6	0.06	(0.03, 0.09)	0.1	3.7	NC	NC	5.6
15–24	13.3	17.0	0.56	(0.39, 0.73)	1.3	4.7	0.06	(0.03, 0.10)	0.2	7.4	NC	NC	14.3
25–34	13.0	16.6	0.58	(0.40, 0.77)	2.9	10.2	0.14	(0.08, 0.19)	0.3	11.1	NC	NC	10.3
35–44	17.0	21.7	0.66	(0.48, 0.84)	5.0	17.6	0.20	(0.14, 0.26)	0.6	18.5	0.02	(0.00, 0.04)	10.0
45–54	11.7	14.9	0.45	(0.30, 0.60)	5.3	18.8	0.23	(0.16, 0.29)	0.6	18.5	0.02	(0.00, 0.04)	9.4
55–64	7.7	9.8	0.37	(0.22, 0.52)	4.0	14.1	0.22	(0.15, 0.29)	0.6	18.5	0.03	(0.00, 0.06)	12.2
65–74	2.3	3.0	0.15	(0.04, 0.26)	3.4	12.1	0.23	(0.15, 0.31)	0.1	3.7	NC	NC	3.1
75–84	3.3	4.3	0.28	(0.11, 0.46)	3.3	11.7	0.30	(0.19, 0.41)	0.4	14.8	0.04	(0.00, 0.08)	11.8
≥85	0.3	0.4	0.08	(0.00, 0.22)	1.2	4.3	0.32	(0.13, 0.50)	0.1	3.7	NC	NC	8.3
Gender													
Male	34.0	43.4	0.38	(0.30, 0.45)	14.3	50.4	0.17	(0.14, 0.20)	1.9	63.0	0.02	(0.01, 0.03)	11.6
Female	44.3	56.6	0.47	(0.39, 0.55)	14.1	49.6	0.16	(0.13, 0.19)	1.1	37.0	0.01	(0.00, 0.02)	7.3
Race													
White	59.3	75.7	0.40	(0.34, 0.46)	23.0	80.9	0.16	(0.14, 0.19)	2.6	85.2	0.02	(0.01, 0.03)	10.0
Black	13.7	17.4	0.45	(0.31, 0.59)	4.8	16.8	0.17	(0.12, 0.23)	0.3	11.1	0.01	(0.00, 0.03)	6.5
Other	5.3	6.8	1.05	(0.54, 1.57)	0.3	1.2	NC	NC	0.1	3.7	NC	NC	25.0
Unknown	0.0	0.0	NC	NC	0.3	1.2	NC	NC	0.0	0.0	NC	NC	NC
Ethnicity													
Non-Hispanic	63.0	80.4	0.43	(0.37, 0.49)	26.2	92.2	0.19	(0.16, 0.21)	2.9	96.3	0.02	(0.01, 0.03)	9.9
Hispanic	15.3	19.6	0.42	(0.30, 0.54)	1.9	6.6	0.06	(0.03, 0.09)	0.1	3.7	NC	NC	5.6
Unknown	0.0	0.0	NC	NC	0.3	1.2	NC	NC	0.0	0.0	NC	NC	NC
Total	78.3	100.0	0.43	(0.37, 0.48)	28.4	100.0	0.17	(0.15, 0.19)	3.0	100.0	0.02	(0.01, 0.02)	9.5

[a]Rates and 95% CIs were not calculated where the total number of cases was <4.

[b]ED visit data are for 2005–2007 only.

[c]Annual mean

[d]Number of CO deaths, divided by the sum of CO deaths and CO hospitalizations, multiplied by 100.

CO = carbon monoxide

ED = emergency department

CI = confidence interval

NC = not calculated

of unknown CO poisoning records contained place information. Of the UNFR CO poisoning records with place information, half (n=107) occurred within the home, while 15% (n=31) occurred at an industrial location. Of the unknown CO poisoning records with place information, 43% (n=28) occurred within the home, while 25% (n=16) occurred at an industrial location.

Chronology. Peak ED visits for UNFR CO poisoning by month were nonsequential, with the highest numbers occurring in November, followed by July, August, and December. When the 2005 ED visits (hurricane related) were removed, peak months were November, September, July, and February. For unknown CO poisoning, the four peak months were the same, regardless of the inclusion of the 2005 cases: June, August, November, and December.

Hospitalizations: 1999–2007

Demographics. Of the 749 CO poisoning hospitalizations during 1999–2007, we classified 744 as confirmed (as opposed to probable) using the CSTE case definition for CO poisoning. Sixty-six percent (n=493) of CO poisonings were UNFR, while 34% (n=256) were of unknown intent. The majority of hospitalizations (84%, n=628) were first admitted through the ED. In general, CO poisonings resulting in hospitalization were fairly self-limiting, as 83% (n=409) of UNFR CO poisoning patients and 68% (n=175) of patients with unknown CO poisoning were discharged to home or self-care. The median length of stay was one day for patients discharged to home and three days for patients discharged to self-care. The remaining patients were transferred to another medical facility or institution, where the median length of stay was four days for UNFR CO poisoning and five days for unknown CO poisoning.

The demographics of the two groups were somewhat different (Tables 1 and 2), although white males still comprised the majority in each category. Black people, who comprise 16% of the Florida population, accounted for 23% of the UNFR CO poisoning group and were more likely than white people to be hospitalized for UNFR CO poisoning (RR=1.6, $p<0.0001$). This relationship was not seen among unknown CO poisoning patients, where there was no difference in hospitalization rates between white and black people (RR=1.1 p=0.7). Individuals of Hispanic origin had a significantly lower rate of hospitalization compared with non-Hispanic people for unknown CO poisoning (RR=0.3, $p<0.0001$). For UNFR CO poisonings, Hispanic and non-Hispanic individuals had the same rate of hospitalization (RR=0.8, p=0.1). The highest rates of hospitalization among both groups (UNFR and unknown CO poisoning) occurred among individuals ≥75 years of age.

Exposure situation and cause. An e-code with information about the cause and situation of CO exposure was noted in hospitalization data for 88% (n=436) of all UNFR CO poisonings. Of these 436 records, 30% (n=131) were related to injury from motor vehicle exhaust fumes, and 33% (n=143) were related to a known source that was not specified in the ICD-9-CM codes, such as generators, industrial kilns, and blast furnaces. Interestingly, white people were more likely than nonwhite people to have CO poisoning related to motor vehicle exhaust (RR=1.8, p=0.02), while nonwhite people were more likely than white people to be exposed to CO via the burning of domestic fuels (RR=2.8, p=0.002). Only 6% (n=15) of unknown CO poisoning cases included information on the cause and situation, the majority (n=12) of which were from motor vehicle exhaust fumes. There was no difference for exposure situation by race.

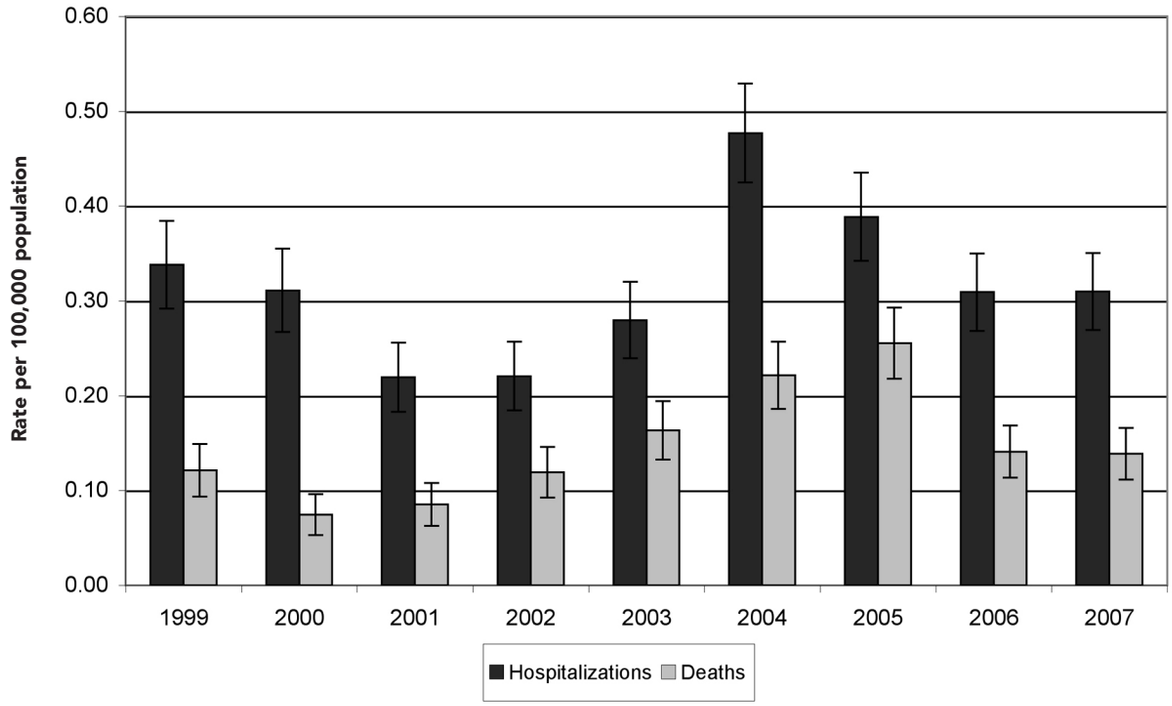
Place of exposure. Place associated with CO poisoning exposure (ICD-9-CM e-code E849) was not uniformly recorded. Only 31% (n=151) of UNFR CO poisoning records and 7% (n=18) of unknown CO poisoning records contained place information. Of those UNFR CO poisoning records with information on place, 70% (n=106) occurred within the home, while 9% (n=13) occurred at an industrial location. The majority (56%, n=10) of unknown CO poisonings also occurred at home.

Chronology. The mean number of hospitalizations by month for UNFR CO hospitalizations displayed two peaks during an average year. The first peak occurred in the winter months (December, January, and February), with a later peak in August. The years 2004 and 2005 (hurricane related) drove a peak for UNFR CO poisoning hospitalizations in September and October (peak not seen in non-hurricane years). Yearly hospitalizations due to UNFR CO poisoning have increased since 2001 (Figure 3), regardless of whether 2004 and 2005 hurricane years were included. For unknown CO poisoning, the mean number of hospitalizations by month peaked in the winter months (December, January, and February), with a smaller peak in July and August.

Mortality: 1999–2007

Demographics. The majority (89%) of all CO poisoning deaths (n=230) were UNFR, while 11% (n=27)

Figure 3. Crude UNFR CO poisoning mortality and morbidity rates among Florida residents, by year: 1999–2007



[a]Hurricane season in Florida is June 1–November 30.

UNFR = unintentional non-fire related

CO = carbon monoxide

were of unknown intent. White males comprised the majority of deaths. Among UNFR CO poisoning deaths, white people had 1.7 times the rate of death of black people (p=0.009). This difference was not statistically significant after adjusting for age (data not shown). In addition, white people had a higher fatality rate than black people for both the UNFR and unknown CO poisoning categories (Tables 1 and 2). UNFR CO poisoning deaths occurred most often among the elderly, with the highest rate among those ≥85 years of age (0.63 deaths per 100,000 population).

Exposure situation and cause. Notes related to cause and situation of death for CO exposure were included in the death certificate for all deaths; however, for 18% (n=47) of all certificates, the description only indicated that the deceased inhaled CO fumes. Thirty-five percent (n=67) of all UNFR CO poisoning deaths where specific cause and situation information were listed were caused by a vehicle left running in an enclosed space. The individual was either in the attached residence or in the enclosed space. Vehicle exhaust fumes were listed as the cause of injury on an additional 34% (n=65) of death certificates, while generator-related exposure accounted for 12% (n=22) of deaths. Eight percent (n=16) of deaths were due to an individual heating their home with a grill, gas oven, or space heater. Again, white people were more likely than nonwhite people to be exposed to exhaust fumes (RR=1.8, p=0.03). Unknown CO poisoning was similar to UNFR exposure: the majority (n=12) of deaths were caused by a vehicle left running in an enclosed space with the individual either in the house or the enclosed space, or death was by inhalation of vehicle exhaust fumes (n=7).

Place of exposure. CO poisoning that resulted in death occurred most frequently in the home: 77% (n=176) of UNFR CO poisonings and 93% (n=25) of unknown CO poisonings. The other main exposure location for UNFR CO poisoning deaths was a street and/or highway.

Chronology. The mean number of fatalities by month for UNFR CO poisonings peaked in January, followed by August and October. Unknown CO poisoning

deaths were highest in June. When the 2004 and 2005 cases were removed, three equal peaks occurred for unknown CO poisoning deaths: March, May, and June. For UNFR CO poisoning deaths, the peaks (hurricane years removed) were January, followed by June and August. UNFR CO poisoning deaths increased steadily in frequency from 2000 to 2005 (Figure 3).

DISCUSSION

The disease burden of CO poisoning in Florida is mostly unexplored, except for a few studies examining CO exposure during specific hurricane seasons. In this study, we examined acute UNFR and unknown CO poisoning among Florida residents using ED data. We also examined hospital discharge and death certificate data to capture cases of severe UNFR and unknown CO poisoning. The death certificate data contained the most descriptive record of CO poisonings. Information related to the intent and mechanism of injury is required before an injury-related death certificate is issued, making this a more complete record for the purposes of poisoning intent and mechanisms.[16] ED and hospitalization data are medical-billings data collected for administrative purposes and often do not contain the intent or mechanism of the injury, as it is not required for reimbursement or treatment.

U.S. Department of Veterans Affairs facilities are not required to report to AHCA; therefore, CO poisoning cases from these facilities may not be included in this analysis. It was not possible to estimate the magnitude of the morbidity underestimation. Additional case underestimation may have occurred for acute CO poisoning (those treated in the ED), as this study was not able to include data from physicians' offices. However, data from the FPICN indicate that only a few dozen calls annually are treated outside of a hospital or ED setting and would not be captured in this analysis.

As previously mentioned, the 2004 and 2005 hurricane seasons devastated Florida. The frequency for UNFR CO poisoning was highest in 2004 and 2005. The rates for this type of poisoning are thought to be slightly inflated due to these events, more so for acute cases than for severe cases. The 2004 and 2005 hurricane seasons affected the distribution of cases by month, producing a rise in cases in the fall that would not normally occur. Interestingly, the overall demographic pattern of those affected by non-fire-related CO poisoning was the same, regardless of the inclusion or exclusion of the 2004 and 2005 cases (data not shown). Additionally, the chronology by year (Figure 3) indicates that hospitalizations and deaths were greater during years with hurricanes or tropical storms. A limitation of this data analysis was that we were not able to tease out the fraction of deaths or hospitalizations due directly to hurricanes, tropical storms, or cleanup efforts.

Examining UNFR severe CO poisoning by month—excluding 2004 and 2005—showed a peak in winter months and August. For acute UNFR CO poisoning, the peak occurred in the fall, while unknown CO poisoning peaked in the winter and spring. A winter peak is consistent with the literature, but this finding was unexpected, as Florida has mild winters, and the risk factors associated with winter CO poisonings were assumed to not be present. However, many Floridians do not have heat or use the heat infrequently, leading to misuse or poor maintenance of fuel-burning devices.

This study shows that the pattern of UNFR CO poisoning mortality and morbidity is similar to what is found in the literature.[1,15,17] Severe CO poisoning resulting in hospitalization or death in Florida affects males more often than females, while acute CO poisoning cases (those treated in the ED) are more prevalent among females than males. The hospitalization and fatality rates are much higher for the elderly (≥75 years of age) than for other age groups. This may be because elderly patients are more likely to mistake their symptoms for other conditions, such as influenza-like illness or fatigue, leading to more severe CO poisoning cases, or because of the higher prevalence of other underlying medical conditions in this age group.[2,3] Highest CO poisoning rates for individuals treated in the ED occurred among adults 24–44 years of age. A previous *Morbidity and Mortality Weekly Report*[1] article indicated that the rates of UNFR CO poisoning ED visits are highest among children younger than 5 years of age; however, this report examined pediatric cases as a group (0–14 years of age), potentially obscuring this finding among Florida cases.

The Hispanic population is less likely overall (not statistically significant) to be affected by UNFR CO poisoning. This finding is in keeping with results seen in New Mexico and California.[18,19] Florida results by race indicate that black people are disproportionately affected by CO poisoning—black people are more likely than white people to be treated in an ED or to be hospitalized for CO poisoning. These findings are consistent with work done by Ralston and Hampson, who hypothesized that socioeconomic status may play a role in the differential exposure to sources of CO poisoning, resulting in higher poisoning rates among black people.[14] Specific socioeconomic data were not available in either study for analysis. However, in our study, we found that among severe cases, the source of CO exposure was associated with racial groups:

exposure was most often related to motor exhaust for white people, while exposure for black people was most often related to stoves and grills. This association was not seen among patients treated in the ED. A possible explanation may be the shortened time period for which ED data were available (2005–2007), with cause and situation results potentially skewed by the 2005 hurricane season.

We found that unknown CO poisoning, like UNFR CO poisoning, had higher rates of acute CO poisoning among females compared with males and that the highest rate of poisoning was found among adults 25–44 years of age. For severe CO poisonings, the highest rate occurred among the elderly (≥75 years of age). Unknown CO poisoning mortality cause and situation data were similar to UNFR CO poisoning mortality, with motor vehicle exhaust being the most frequent cause. And while the most frequent exposure cause was different for unknown and UNFR CO poisoning morbidity, motor vehicle exhaust fumes was one of the top two exposure causes for both. Based on these similarities, prevention methods to reduce UNFR CO poisonings should also serve to reduce unknown CO poisonings.

Within the past five years, Florida has enacted policies to reduce unintentional CO poisoning. In the fall of 2008, CO poisoning became a reportable disease condition per changes to a Florida statute. This action will provide much needed data related to CO poisoning and exposure causes, injury locations, and overall injury details. Lack of this information is a current limitation of the datasets used in this study. Making CO poisoning a reportable disease will also allow for easier and more rapid identification of clusters—an acknowledged limitation when using administrative data. As the majority of poisonings occur within the home, a single exposure could naturally affect multiple individuals. Additionally, analysis of new CO surveillance data will provide further information on CO poisoning by race, which is necessary to understand the burden to minority populations. In July 2008, CO-detector legislation went into effect requiring all new construction with a fossil fuel-burning heater or appliance, fireplace, or attached garage to have an operational alarm. This new legislation will also help to reduce the number of severe CO poisoning cases. However, CO alarms are a secondary prevention method. It is important for individuals to understand that the best way to prevent CO poisoning is through the proper installation, maintenance, and operation of fuel-burning devices.

Prior to this study, Florida focused its CO poisoning prevention messages on generator safety and fuel-burning equipment used during cleanup following disasters. Florida addresses these issues with awareness activities in multiple languages focused on generator safety, issuing CO poisoning prevention messages and materials after natural disasters. The 2004 and 2005 hurricane seasons resulted in increased sales of generators, which may currently be used in non-disaster situations, such as when the power is disconnected due to nonpayment or more routine outage occurrences. Increased numbers of generators lead to an increased possibility of misuse. Therefore, distribution of information on generator safety should continue during and outside of disaster situations.

CONCLUSION

CO poisoning is preventable, and, while further data is required to supplement this analysis, the burden of disease within Florida may be greatly reduced with appropriate public messages. As shown by our study, a large percentage of poisonings are due to motor vehicle exhaust. In conjunction with prior messages, the public should be reminded of the dangers of leaving a vehicle idling, especially within an enclosed space. In addition, prevention messages including symptom awareness should target the elderly, as they are more likely to suffer from severe outcomes. Finally, a surprise finding was that CO poisoning in Florida peaks during the winter months, indicating a need for year-round educational campaigns.

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