Storm-Related Carbon Monoxide Poisoning: Lessons Learned from Recent Epidemics

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Hampson NB, Stock AL. Storm-Related Carbon Monoxide Poisoning: Lessons Learned from Recent Epidemics. Undersea Hyperb Med 2006; 33(4): 257-263. Over the past 15 years, a number of epidemics of carbon monoxide (CO) poisoning related to various storms have been reported. While the geographical location of these outbreaks and the types of storms involved has been diverse, review of the events reveals a number of common factors and themes. This paper summarizes the details of 9 published reports describing CO poisoning associated with 11 different storms. When common patterns were examined, five "lessons to be learned" from the experience were derived. They are (1) loss of electrical power can lead indirectly to carbon monoxide poisoning, (2) campaigns to educate the public about risks for CO exposure should be timed regionally to coincide with the peak risk for typical storms, (3) significant opportunities exist for prevention of generator-related CO poisoning, (4) there is a window of time for effective communications regarding the dangers of CO poisoning even after a storm strikes, and (5) the major sources of CO responsible for poisonings can be related to the type of storm and are predictable. It is hoped that each of these lessons are used to develop public programs designed to prevent storm-associated CO poisoning in the future.

INTRODUCTION

Acute carbon monoxide (CO) poisoning is common in the United States, resulting in an estimated 40,000 emergency department visits (1), 2,400 intentional deaths, and 1,400 accidental deaths annually (2). Intentional CO exposures are almost always isolated suicide attempts by a single individual. They are separate events, not statistically associated in time (3). Episodes of accidental CO poisoning may involve one or multiple persons. Further, accidental incidents of CO poisoning may occur in clusters or outbreaks when external influences cause many individuals to pursue activities resulting in CO exposure. An example of this is CO poisoning following severe storms.

While it is encouraging that the CO poisoning death rate from some causes has decreased (e.g. accidental motor vehicle exhaust exposure) (2), CO exposure related to severe storms appears to remain common. Over the past one and one-half decades, a number of reports have described storm-related CO poisoning. It is the purpose of this review to attempt to identify common factors in these epidemics in the hope that such knowledge leads to prevention success similar to that achieved by introduction of the catalytic converter in automobiles.

The following outbreaks of carbon monoxide poisoning following various storms will serve to illustrate the risk for CO exposure as a result of varied meteorological events.

These episodes will be examined for common themes to help identify prevention strategies.

REPORTS OF STORM-RELATED CARBON MONOXIDE POISONING

Washington State, 1993 (4,5).

On January 20, 1993, a severe windstorm entered Washington State from the south at 08:00 AM. The maximum wind gust was 94 miles per hour, resulting in loss of electrical power to 776,000 residents of Western Washington. Temperatures dropped to near freezing for four consecutive nights following the storm. At least 81 patients from 30 incidents were treated in 13 Western Washington hospital emergency departments (EDs) for CO poisoning over that time. The two main sources of CO were charcoal briquettes (47% of incidents) and gasoline-powered portable electrical generators (33%). Of the 81 patients identified, 35 (43%) were referred for hyperbaric oxygen (HBO_2) treatment of severe poisoning. Patients presented to the ED in increasing numbers for the first three days after the storm struck, then appeared with decreasing frequency, presumably due to restoration of electrical power (Figure 1). Of the total group, 78% presented on day 2 or day 3. The majority of poisoned patients presented after sundown (approximately 17:00 PM) each night (Figure 2). The onset of darkness and resultant fall in temperature presumably led many to turn to hazardous alternatives for home heating and electricity for lighting, resulting in the indoor use of charcoal and improper use of generators.

Northeastern United States, 1996 (6).

A major snow blizzard from January 6-8, 1996 resulted in a different type of CO poisoning epidemic. A total of 25 cases were reported, 22 in New York City and 3 in Philadelphia. All 25 cases were due to snow-obstructed vehicle exhaust systems as drivers sat in stranded cars and ran engines to counter cold temperatures. Two patients were treated with hyperbaric oxygen. Two poisonings were fatal. Detailed information on time from storm onset to ED presentation was not reported.

Maine, 1998 (7).

On January 7, 1998, a severe ice storm struck the northeastern United States and southeastern Canada. Over 600,000 Maine residents lost electrical power, some for up to 2 weeks. Hospitals across the state evaluated 400 cases of CO poisoning. Analysis of data from 4

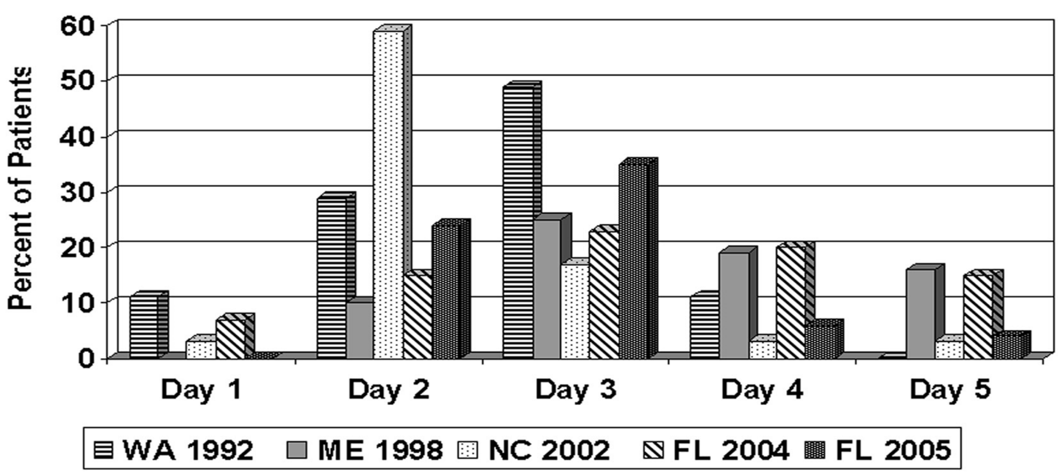

Fig. 1. Day of emergency department presentation by CO-poisoned patients following major storms (references 5,7,8,11,12). Data points represent the percentage of total patients reported in each epidemic.

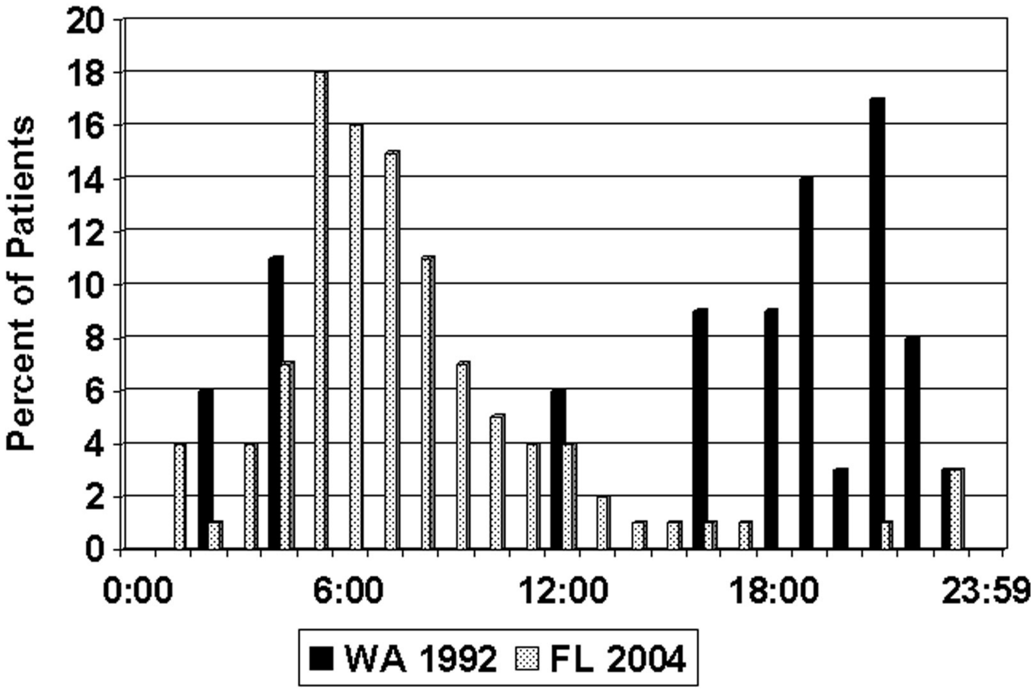

Fig 2. Hour of emergency department presentation by CO-poisoned patients following major storms (references 5,11). Data points represent the percentage of total patients reported in each epidemic.

hospitals identified 100 total cases, 5 treated with HBO_2, and 1 fatality. Patients presented to the ED for 13 days after the storm struck. Of the total group, 70% presented on days 2 thorough 5 (Figure 1). Individuals were poisoned in 42 incidents, 6 of which involved two sources of CO. The most common sources included generators (71% of incidents), space heaters (26%), and charcoal briquettes (5%).

North Carolina, 2002 (8,9).

A winter ice storm struck central North Carolina on December 4, 2002. By the following day, over 1 million utility customers were without electrical power due to storm-related outages. Temperatures remained unseasonably low for the next 5 days. A total of 29 patients were treated with HBO_2 for severe CO poisoning at Duke University Medical Center in Durham. A majority of patients (76%) presented on day 2 or 3 after the storm struck (Figure 1). The only sources of CO responsible for their exposures were charcoal briquettes (72%) and gasoline-powered electrical generators (28%).

In another region of the state (Mecklenburg County), 79% of households lost electrical power from the storm. A total of 124 persons had symptomatic CO poisoning, including 25 with severe poisoning and one death. The major sources of CO were charcoal or propane grills (43% of incidents), electric generators (25%), space heaters (5%), stoves or ovens (5%) and wood fires (5%) (Table 1, see page xxx). Information on time from storm onset to ED presentation and use of hyperbaric oxygen treatment was not reported.

New York, 2003 (10).

An ice storm struck the Rochester, New York area January 4, 2003 resulting in power outages to an estimated 182,000 people for as long as 6 days. Over the week following the storm, 45 patients were treated for CO

	Month	Type of Storm	Cases of CO Poisoning Reported	CO Deaths	Treated with HBO_2	Major Sources of CO			
						Charcoal	Generator	Motor vehicle	Space heater
Washington State, 1993 (4,5)	January	Windstorm	81	0	35	47%	33%	1%	1%
Northeastern US, 1996 (6)	January	Blizzard	25	2	2	0%	0%	100%	0%
Maine, 1998 (7)	January	Ice storm	400	1	5	5%	71%	0%	26%
North Carolina, 2002 (8)	December	Ice storm	29	*	29	72%	28%	0%	0%
North Carolina, 2002 (9)	December	Ice storm	124	1	*	43%	25%	0%	5%
New York, 2003 (10)	January	Ice storm	45	0	0	0%	77%	0%	15%
Eastern US Seaboard, 2003 (11)	September	Hurricane	8	8	*	*	≥ 25%	*	*
Florida, 2004 (12)	August-September	Hurricanes	167	6	77	0%	96%	2%	0%
Gulf Coast, 2005 (13)	August	Hurricane	51	5	37	0%	98%	0%	0%

Table 1. Characteristics of recent epidemics of storm-related CO poisoning. * = data not reported

exposure at the emergency department of the region's major medical center. No patients were treated with HBO_2. All patients survived. The only sources of CO were generators (77%), propane or kerosene heaters (15%), and fireplaces (8%). Interestingly, when data were compared with the hospital's experience following a similar storm 12 years earlier, CO exposures from charcoal or gas grills decreased from 11% in 1991 to 0% in 2003. Information on time from storm onset to ED presentation was not reported.

Eastern US Seaboard, 2003 (11).

Hurricane Isabel came ashore September 18, 2003 with 100 MPH winds in the Outer Banks of North Carolina and then moved up the Eastern seaboard. Major power outages occurred in North Carolina (67,000 customers), Virginia (1.8 million), Maryland (133,000), New Jersey, Pennsylvania, New York, and Rhode Island. Of 40 total fatalities from the storm reported in the news media, 8 were due to CO poisoning. In at least 2 cases, deaths were due to improperly ventilated electrical generators. Information on other CO sources, time from storm onset to ED presentation and use of hyperbaric oxygen treatment was not reported.

Florida, 2004 (12).

Florida experienced 4 major hurricanes from August to September, 2004, producing electric power outages in several million homes. Generators were used in at least 18% of homes with power outages. Among those using a generator, 5% reported operating them inside a home or garage. At least 167 persons were treated for CO poisoning, with 6 deaths. Of those treated, 77 (46%) received HBO_2. Portable generators were the source of CO in 96% of nonfatal and 100% of fatal incidents. Among those poisoned by generators, 34% were operated outdoors, 34% in an attached garage, 13% inside a home or basement and 8% on an attached deck. The majority of generators operated outdoors were located near windows or window-mounted air conditioners, allowing CO to enter the home. Of the total group poisoned, 68% presented for medical evaluation on days 2-4 after the respective hurricane struck (Figure 1). The majority of patients (66%) arrived at the emergency department from 05:00-10:00 AM, attributed to overnight CO exposure during sleep as generators were used to power refrigerators, fans and air conditioners (Figure 2**).**

Gulf Coast, 2005 (13).

Hurricane Katrina made landfall on the Gulf Coast of the United States on August 29, 2005. Widespread power outages and property damage resulted. Local and state public health infrastructure for disease surveillance was disrupted. The Centers for Disease Control and Prevention (CDC) requested the assistance of the Undersea and Hyperbaric Medical Society (UHMS; Dunkirk, MD) in tracking cases of CO poisoning resulting from the storm, especially those treated with HBO_2. UHMS members in affected states were notified of the request and reported cases by email to author NBH who then forwarded summed data on a daily basis to author ALS at the CDC.

From August 29-September 24, 2005, a total of 51 cases of CO poisoning were reported by hyperbaric facilities in Alabama (24 nonfatal cases), Louisiana (16 nonfatal and 5 fatal cases), and Mississippi (6 nonfatal cases). Of the 46 nonfatal cases, 37 patients were treated with HBO_2. Among the total cases, 59% occurred on day 2 or 3 after the storm struck (Figure 1). Portable generators were the source of CO for 45 nonfatal and all 5 fatal cases (Table 1). One nonfatal case was associated with use of a gasoline-powered pressure washer.

During this same time period, the American Association of Poison Control Centers reported a total of 58 calls relating to possible CO exposures, 8 in Mississippi, 21 in Alabama and 29 in Louisiana. No calls relating to fatalities were received. The sources of the CO exposures are not known.

COMMENT

Analysis of the details of these epidemics of storm-related carbon monoxide poisoning allows extraction of common themes that may contribute to disease prevention in the future. These themes include (1) the types of storms associated with CO poisoning, (2) the time of year that they occur, (3) typical sources of CO, (4) peak days for poisoning after a storm strikes, and (5) the time of day that individuals are poisoned.

The storm types responsible in the reports reviewed included a wide variety of meteorological events, namely windstorm, blizzard, ice storm, and hurricane. The common factor for all except the blizzard was an accompanying loss of electrical power to thousands or even millions of utility customers. Loss of power clearly leads to activities with an inherent risk for CO exposure. Relationships between the type of storm causing power outages, specific CO sources, and temporal epidemiology of both will be discussed subsequently. The first lesson from this review, however, is that ***loss of electrical power can lead indirectly to carbon monoxide poisoning***. Hurricanes are always anticipated and wind/ice storms are often predicted. Electrical utility companies, governmental agencies, and media services can be used to promulgate warnings with regard to CO when power outages are expected and soon after they occur. Television weather channels are widely watched as major storms approach. Including warnings about CO exposure risks in such programming could be a valuable public service.

Storm-related CO poisoning outbreaks have a predictable seasonal epidemiology. Poisonings related to wind or ice storms occur in winter months (esp. December-January), while those due to hurricanes occur in late summer to early autumn (esp. August-September). The second lesson from this review is that ***campaigns to educate the public about risks for CO exposure should be timed regionally to coincide with the peak risk for typical storms*** in that part of the country.

The most common sources of CO causing poisoning following a major storm are portable, gasoline-powered, electrical generators and indoor use of charcoal briquettes. Following widespread CO poisoning from charcoal briquettes after the 1992 Washington State storm (4,5), as well as the subsequent realization that most individuals poisoned in this fashion are non-English speaking first generation immigrants to the US (3), the US Consumer Product Commission (CPSC) to reviewed and ultimately revised the government-mandated warning label printed on all bags of charcoal sold in this country starting in November 1997 (15). This may have contributed to the reported decline in US deaths due to charcoal-related CO poisoning after that date (16,17). It is also speculated to have played a role in the complete disappearance of charcoal-related CO exposures seen between 1991 and 2003 epidemics following ice storms in New York State (10).

No such warning label about CO poisoning is required on portable electrical generators. A recent study found that the most common reason for hazardous use of generators among individuals poisoned in this fashion was ignorance of risk of CO exposure (18). This suggests that warning labels and public education programs have the potential to impact incidence of the disease. In addition, engineering solutions and more stringent controls on generator emissions output would undoubtedly help. The third lesson from this review is that ***significant opportunities exist for prevention of generator-related CO poisoning***.

As illustrated in Figure 1, the majority (63%) of CO poisonings occur on days 2 or 3 following a storm. This suggests that ***there is a window of time for effective communications regarding the dangers of CO poisoning even after a storm strikes***, the fourth lesson learned from this review. Radio broadcasts would be predicted to be most effective. In the case of a blizzard with cars stranded in snow, most vehicle occupants are probably listening to the car radio for information about their status. Admonitions to clear snow-obstructed tailpipes would likely be heeded. For those without electrical service due to wind/ice storms or hurricanes, many will listen to battery-powered radios for public service updates and other news of the storm.

Finally, review of the published experience reveals that ***the major sources of CO responsible for poisonings can be related to the type of storm and are predictable***. Among those poisoned following winter wind or ice storms, indoor use of charcoal briquettes was the primary source in two of three epidemics (Table 1), but generators are becoming more of an issue. Such patients tended to preset to the emergency department between the hours of 4:00 PM and midnight, suggesting that charcoal is being used for cooking and/or heating after sundown when the temperature drops. Following hurricanes, all three epidemics reviewed demonstrated that portable generators are the predominant CO source (Table 1). One report described time of day for presentation to the ED (12). Interestingly, these patients tended to present between 4:00 AM and noon, suggesting that exposures probably occur during sleep as generators might be run to power electric fans or air conditioners. Recognition of CO sources common to different storm types has the potential to allow very specific and targeted warning messages.

In summary, storm-related CO poisonings are common, predictable and likely very preventable. Public health efforts should be focused on this current area of significant morbidity and mortality.

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