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Original Contributions

EPIDEMIC CARBON MONOXIDE POISONING FOLLOWING A WINTER STORM

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☐ **Abstract—Hospital emergency departments were surveyed to estimate the number of patients treated for carbon monoxide (CO) poisoning after a severe winter storm disrupted electrical service in western Washington State. At least 81 persons were treated. The two main sources of CO were charcoal briquettes (54% of cases) and gasoline-powered electrical generators (40% of cases). Of the 44 persons affected by CO from burning charcoal, 40 (91%) were members of ethnic minority groups; 27 did not speak English. All persons affected by CO from generators were non-Hispanic Whites. This was the largest epidemic of storm-related CO poisoning reported in the United States. This epidemic demonstrated the need to anticipate CO poisoning as a possible consequence of winter storms in cold climates and to make preventive messages understandable to the entire population at risk, including those persons who do not understand written or spoken English. © 1997 Elsevier Science Inc.**

☐ **Keywords—carbon monoxide; disaster; winter storm; ethnic minority; prevention**

INTRODUCTION

A major epidemic of carbon monoxide (CO) poisoning occurred after a severe winter storm struck western Washington State during the morning of 20 January 1993. Charcoal briquettes and gasoline-powered electrical generators were the principal sources of CO. Although previous reports have described CO poisoning following winter storms in the eastern United States (1–3), the large number and wide distribution of cases following this storm are unique.

Unintentional CO poisoning is a substantial health problem in the United States, causing an estimated 11,547 deaths from 1979 through 1988 (4). The United States Consumer Product Safety Commission estimates that there was an average of about 28 charcoal-related CO deaths per year from 1986 through 1992 (5). Charcoal briquettes are not an uncommon source of CO poisoning in western Washington State; 16% of the 509 unintentional poisoning cases that required hyperbaric oxygen (HBO_2) treatment between October 1982 and October 1993 involved charcoal (6).

Our investigation suggests that CO poisoning following severe winter storms should be anticipated. It also suggests that preventive messages are important public health measures, but that they should be understandable to those in the community who neither read nor speak English.

MATERIALS AND METHODS

Background

The storm entered Washington State from the south (Figure 1) and reached the Seattle–Tacoma metropolitan

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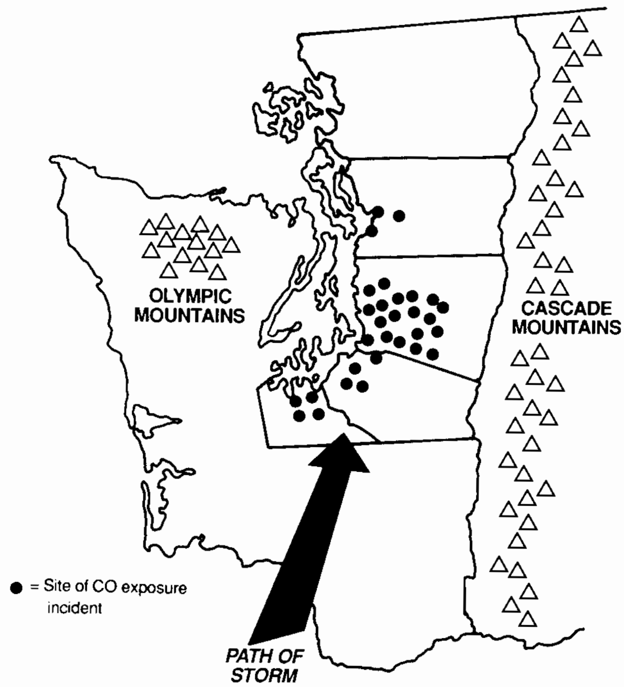

Figure 1. Location of unintentional CO poisonings following a winter storm, Washington State, 20–23 January 1993. A case of CO poisoning was defined as a venous or arterial COHb level of ≥2.0% (for nonsmokers) or ≥9% (for smokers) in a person who sought medical care in an ED in western Washington during 20–23 January 1993 and had not been involved in a fire or intentional CO exposure. Each dot represents one exposure incident.

area between 8:00 AM and 9:00 AM. Wind gusts reached 88 miles per hour in Seattle (Clifford Mass, PHD, Department of Atmospheric Science, University of Washington, personal communication). Temperatures were near freezing during the four nights following the storm. An estimated 776,000 residents lost regular electrical power, some for up to 1 wk. Local news media reported that many residents used charcoal briquettes and gasoline-powered electrical generators for cooking and heating.

Poisoning occurred in residents of 4 of 19 western Washington counties: Snohomish, King, Pierce, and Thurston. The total population of these 4 counties in 1990 was 2,720,402, with 84% non-Hispanic Whites, 6% Asian/Pacific Islanders, 5% Blacks, and 3% Hispanics (7). The baseline annual incidence of unintentional CO poisoning in the area is unknown. However, the Hyperbaric Medicine Department of the Virginia Mason Medical Center in Seattle, the primary provider of HBO_2 therapy in the region, treated 5 unintentional CO poisoning cases during January 1992 and 4 such cases during January 1994.

Case Definition and Identification

A case of CO poisoning was defined as a venous or arterial blood carboxy-hemoglobin (COHb) level of at least 2% for nonsmokers or 9% for smokers in a person who was treated for CO poisoning in any hospital emergency department (ED) in Washington west of the Cascade Mountains during 20–23 January 1993 and was known not to have been involved in a fire or intentional CO exposure. These COHb cutoff levels approximate the 95th percentiles for nonsmokers (1.7%) and current smokers (8.7%) reported in a previous population-based study (8).

The ED log books or hospital electronic records were used to identify potential cases at all 53 hospital EDs in western Washington. Data were abstracted from medical records by ED staff or by one of the authors using a standard form.

RESULTS

Eighty-one case patients received treatment at 13 hospitals (median = 4 patients/hospital, range = 1–21 patients). They represented 30 separate CO exposure incidents (median = 2 patients/incident, range = 1–9 patients). The median patient age was 26 yr (range = <1–87 yr); 49 (61%) were female. There were 40 (49%) non-Hispanic Whites, 25 (31%) Asians, 13 (16%) Hispanics, 2 (3%) persons of Middle Eastern ancestry with unknown ethnicity, and 1 (1%) Black.

Table 1. Unintentional Carbon Monoxide Poisoning[a] Cases (N) and Incidents, by Source of Carbon Monoxide and Race or Ethnicity, Washington State, January 20–23, 1993

	Race or Ethnicity											
	Non-Hispanic White		Asian		Hispanic		Black		Mid-East Unknown		Total	
	N	Incidents	N	Incidents	N	Incidents	N	Incidents	N	Incidents	N	Incidents
Source of CO												
Charcoal	0	0	25	10	12	2	1	1	2	1	40	14
Charcoal/propane stove	4	1	0	0	0	0	0	0	0	0	4	1
Generator	26	10	0	0	0	0	0	0	0	0	26	10
Generator/space heater	6	2	0	0	0	0	0	0	0	0	6	2
Space heater/ propane stove	0	0	0	0	1	1	0	0	0	0	1	1
Propane lantern	3	1	0	0	0	0	0	0	0	0	3	1
Automobile	1	1	0	0	0	0	0	0	0	0	1	1
Total	40	15	25	10	13	3	1	1	2	1	81	30

[a] A venous or arterial carboxyhemoglobin level of ≥2.0% (for nonsmokers) or ≥9% (for smokers) in a person who sought medical care in an Emergency Department in western Washington during January 20–23, 1993 and had not been involved in a fire or intentional CO exposure.

All poisoning incidents occurred in the storm path and within areas known to have widespread interruption of electrical power (Figure 1). Case patients began seeking care within 9 h of the storm's arrival; 64 (79%) patients presented between 6:00 PM and 6:00 AM during the three nights following the storm.

Eleven (14%) patients lost consciousness. Among all patients, the median COHb level on initial presentation for medical care was 17% (range = 2–46%). Thirty-five (43%) patients, including all with loss of consciousness, were treated with HBO_2, and the other 46 received oxygen by mask. Eight (10%) patients were hospitalized. No identified case was fatal. The coroners or medical examiners of the four counties where cases occurred did not record any unintentional CO poisoning deaths during the 4-d period.

Forty-four (54%) of the 81 cases involved charcoal briquettes. The source of CO was indoor burning of charcoal briquettes only in 14 incidents (40 persons), a gasoline-powered electrical generator in 10 incidents (26 persons), a generator and propane-powered space heater in 2 incidents (6 persons), charcoal briquettes and a propane stove in 1 incident (4 persons), a space heater and a propane stove in 1 incident (1 person), an automobile in 1 incident (1 person), and a propane lantern in 1 incident (3 persons).

Of 44 patients poisoned with CO from charcoal briquettes, 40 (91%) were members of ethnic minority groups, including all 25 case patients of Asian ancestry (Table 1). All 32 persons who were exposed to CO from gasoline-powered generators were non-Hispanic Whites. Twenty-seven (66%) of the 41 patients who were members of ethnic minority groups did not speak English, including 13 (52%) of the Asians and 12 (92%) of the Hispanics.

Initial reports about CO poisoning and the danger from indoor use of charcoal and gasoline-powered generators were first carried by television and radio stations during the late evening of 21 January. Newspaper stories first appeared the following day. All of this news coverage was in English only.

DISCUSSION

This is the largest epidemic of storm-related CO poisoning to be documented in the United States. Previous reports have described up to 22 cases in each of several large storms (1–3). The 81 cases represent the minimum number of storm-related poisonings and may be a substantial underestimate of the true CO morbidity. We identified 6 symptomatic persons who were treated for CO poisoning and were epidemiologically linked to case patients, but who did not meet our case definition because COHb levels were not measured. We would have missed additional cases if patients were treated in clinics; if physicians did not recognize nonspecific symptoms, such as headache or nausea, as being caused by CO; if COHb levels had dropped to the normal range prior to testing; or if coroners and medical examiners neither sought nor found evidence of CO poisoning during death investigations.

This event was notable because of the prominence of charcoal briquettes as the source of CO, especially for

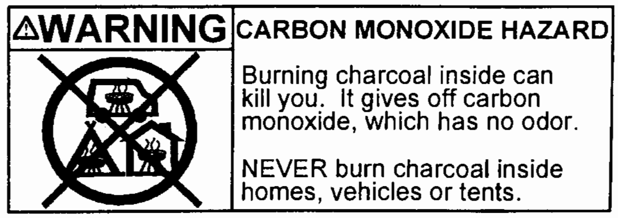

Figure 2. Warning of CO poisoning required by the U.S. Consumer Product Safety Commission on bags of charcoal briquettes packaged after 3 November 1997.

persons of Asian ancestry. Indoor cooking with charcoal briquettes has been recognized as a common cause of CO poisoning in Korea (9). Non-storm-related CO poisoning of Asians (6,10,11) and non-English speaking persons (6,12,13) from indoor charcoal burning has also been noted in the United States. Following this storm, the proportion of cases in Asians was more than five times the expected number based on the ethnic distribution of the general population of the four counties where cases occurred.

The effect of news media reports on the incidence of CO poisoning following this storm cannot be determined. However, most of the news coverage took place before the evening of 23 January and, despite more than 160,000 persons remaining without electrical power, we did not identify any new cases after that time. This observation suggests that media attention on the dangers of CO poisoning might have prevented some cases. In December 1995, television and radio stations and newspapers issued warnings about the danger of CO poisoning 24 h before a similar storm disrupted electrical power to more than 400,000 persons in western Washington. Those early warnings may have contributed to the apparent absence of storm-related CO poisoning, although warmer weather, a shorter duration of power disruption, and the arrival of the storm in the Seattle area after the dinner hour also probably played a role.

Urgent and emergency medical care providers should be familiar with the symptoms and treatment of CO poisoning and should be aware of potential poisonings when extensive electrical power interruptions occur during cold weather. Public health and emergency agencies should include CO poisoning among the possible consequences of these storms and develop contingency plans for CO poisoning surveillance and for warning the public about the dangers of using charcoal briquettes, gasoline-powered generators, or other CO-producing energy sources in poorly ventilated areas. Accurate weather forecasting can allow warnings to be made before a storm arrives; once electrical service is disrupted, dissemination of television and radio messages is more difficult. The probability of warnings reaching a large proportion of residents increases if a variety of media are used, including newspapers, television, and radio. We have generally found television health and weather reporters to be interested in including CO warnings in stories about severe storms.

At least 11.5 million persons age 18 yr or older in the United States do not speak English well (7), and many do not read any language well. The disproportionate number of non-English-speaking persons who were poisoned following this storm illustrates the need to produce prevention messages that they can understand. The Consumer Product Safety Commission, partly in response to this incident, has ruled that bags of charcoal briquettes packaged after 2 November 1997 must carry enhanced CO warnings (Figure 2) that include a pictogram targeted at persons who do not read English and 7th-grade-level text for those who read it poorly (5).

The feasibility of community-based education programs for minority populations depends on local circumstances, including the size of the minority community, the existence of non-English-language news media and minority community organizations, and the resources of public health agencies. Culturally appropriate educational programs should focus on important sources of CO (e.g., charcoal briquettes in the Asian and Hispanic communities) and the early symptoms of CO poisoning. Timely dissemination of multilingual warnings in the face of a major storm requires careful preparation of accurate, understandable printed information and press releases long before the storm develops. This dissemination may require considerable resources in an urban area such as King County, Washington, where the health department publishes information in at least eight languages. Advance contact with the English- and non-English-language print and electronic media may be helpful. If non-English-speaking ethnic minority residents live in a reasonably well-defined area, minority community organizations might consider the approach used by the fire department in a small western Washington city after this storm, where volunteers went door to door, warning residents of the danger of CO poisoning.

Two recent storms in the Pacific Northwest have again demonstrated the serious and potentially fatal danger of storm-related CO poisoning and the disproportionate involvement of ethnic minorities. In November 1996, an ice storm disrupted electrical service to more than 100,000 homes and businesses in Spokane, Washington. Nine cases of CO poisoning were reported following that storm, including 2 fatal cases in Vietnamese-Americans that resulted from indoor burning of charcoal briquettes. In December 1996, heavy snow left several hundred thousand Seattle-area residents without electrical power. Among 15 subsequent cases of unintentional CO poisoning requiring HBO_2 treatment, the source of CO was charcoal briquettes in 6, gasoline-powered electrical generators in 5, and propane stoves in 4. Eight cases, including all 6 that involved charcoal briquettes, were in members of minority groups.

Unintentional CO poisoning following a severe winter storm is a serious health problem that can be anticipated and prevented. Health care workers can make a major contribution to the public's health by promoting awareness of the danger of CO poisoning, by reminding the news media to include warnings about CO poisoning in stories about severe storms, and by maintaining an awareness of the potential for CO poisoning after the storm arrives so that adequate treatment can be provided.

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