A Comparison of Carbon Monoxide Exposures After Snowstorms and Power Outages

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Background: Unintentional carbon monoxide poisoning occurs frequently after natural disasters. Although the epidemiology of carbon monoxide exposures that occur after power loss storms has been reported, few publications detail the characteristics of carbon monoxide exposures after massive snowstorms.

Purpose: To compare the differences in patient characteristics of carbon monoxide exposures after a snowstorm and power loss storm.

Methods: In 2013, a retrospective review was conducted of patient characteristics and exposure data from all carbon monoxide cases reported to the Connecticut Poison Control Center in the days following both a major snowstorm in 2013 and a winter storm that caused extensive power outages in 2011.

Results: Portable generators were the most common source of carbon monoxide exposure after a storm that resulted in power losses; car exhaust was the most frequent source of exposure after an extensive snowstorm. Most exposures occurred within the first day after the snowstorm, and on the second and third days after the power outage storm. There were no significant differences between the two storms in terms of patient age, gender, or median carboxyhemoglobin concentration.

Conclusions: Future public health and medical education regarding the dangers of carbon monoxide in the aftermath of storms should include attention to the differences in the typical exposure sources and timing.
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Introduction

Carbon monoxide is a colorless, odorless, tasteless gas formed from the incomplete combustion of carbon-based fuel products. Owing to its non-irritant nature and non-specific clinical effects, carbon monoxide poisoning is often under-recognized. In 2011, 13,862 carbon monoxide exposures were reported to U.S. Poison Control Centers[1]; of these, 12,136 were unintentional exposures.

Unintentional non–fire-related carbon monoxide exposures often occur with increased frequency after natural disasters. The epidemiology of unintentional non–fire-related carbon monoxide exposures associated with storms resulting in widespread electrical power loss is well described in the medical literature.[2–5] Following such a "power loss" storm, the majority of carbon monoxide exposures occur secondary to indoor use of gasoline-powered generators, propane-powered heaters and lanterns, and charcoal grills for heating and cooking purposes.[6] Generally, there is a delay of up to 24 hours after the storm ends before a significant number of exposures is reported. The number of exposures typically peaks approximately 2—3 days after the storm ends and then gradually declines. In one report of storm-related carbon monoxide poisoning, more than three quarters of affected patients presented for medical care on the second or third day after the storm.[7]

Carbon monoxide poisoning is also a concern in the aftermath of snowstorms. Snow drifts may block home heating vents, causing indoor accumulation of carbon monoxide in homes with non-electric heating sources. In 2005, snow drifts blocked a heating vent in a Massachusetts home, leading to fatal carbon monoxide poisoning in a 7-year-old girl; subsequently, Massachusetts mandated the use of carbon monoxide detectors in homes with attached garages or non-electric heating sources.[8] When large amounts of precipitation accumulate during snowstorms, vehicle exhaust systems may also become obstructed with snow. After the engine is started,

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Table 1. Storm characteristics

Dates of storm	October 29–30, 2011	February 8–9, 2013
Type of storm	Power loss	Massive snowstorm
Maximum snowfall (Bradley International Airport, Windsor Locks, Connecticut; inches)[a,b]	12.3	22.3
Highest reported snowfall across state of Connecticut (inches)[a,b]	17	40
Average temperature reported (Bradley International Airport, Windsor Locks, Connecticut; °F)[c]	38	22.5
Power outages across state of Connecticut	831,000	73,000

[a]Public information statement: spotter reports. Taunton MA: National Weather Service, 2011. www.erh.noaa.gov/box/pnsevents/Oct_29-30_2011/Oct_29-30_2011_BOXPNS.txt.
[b]Public information statement: spotter reports. Taunton MA: National Weather Service, 2013. www.erh.noaa.gov/box/pnsevents/Feb_08-09_2013/Feb_08-09_2013_BOXPNS.txt.
[c]Observed weather reports. Boston MA: National Weather Service, 2011–2013. www.nws.noaa.gov/climate/index.php?wfo=box.

exhaust can back up inside the passenger compartment. Passengers then inhale the gaseous components of the exhaust, which include carbon monoxide. Automobile exhaust represents another source of carbon monoxide poisoning that can occur after a heavy snowfall.[9] Although there are numerous reports of the epidemiology of carbon monoxide exposures after power loss storms, fewer published reports describe the characteristics and epidemiology of carbon monoxide exposures after snowstorms.

The state of Connecticut has recently experienced both a severe power loss storm and a record-setting snowstorm. Characteristics of these storms, which occurred in October 2011 and February 2013, are depicted in Table 1. A significant number of unintentional carbon monoxide exposures were reported to the Connecticut Poison Control Center after both storms. In order to elucidate the epidemiology and characteristics of carbon monoxide exposures related to a massive snowstorm compared to a power loss storm, we sought to assess and compare differences in the patterns of exposure as well as the treatments received by patients exposed to carbon monoxide during both of these storms. The overall purpose of this study was to compare the differences in patient characteristics of carbon monoxide exposures after a snowstorm and a power loss storm to enhance medical and public health knowledge of these types of exposures.

Methods

IRB approval for this retrospective, descriptive study, conducted in 2013, was obtained at both Hartford Hospital and the University of Connecticut Health Center, the location of the Connecticut Poison Control Center. The Connecticut Poison Control Center serves the state of Connecticut. It is staffed by specially trained registered nurses and pharmacologists and handles more than 30,000 calls each year from residents of Connecticut and health care facilities concerning human toxicologic exposures. All calls fielded by the Poison Center are entered into a national computerized database (TOXICALL®, Computer Automation Systems, Aurora CO) by the Poison Center staff.

Information entered into TOXICALL includes patient demographic information, caller information, exposure sources, exposure dates, clinical effects, and administered therapies. Exposure sources are identified by standardized numerical codes; a free-text area exists for documentation of additional information.

Date ranges for this study were defined as October 29–November 2, 2011 (days 0–4 after the power loss storm), and February 8–12, 2013 (days 0–4 after the start of the snowstorm, which lasted from February 8 until the early morning hours of February 9). The TOXICALL database was queried to identify all adult and pediatric human cases in Connecticut in which "carbon monoxide" was coded as a source of toxicological exposure during the defined date ranges. During these date ranges, there was one fire-related carbon monoxide exposure reported to the Connecticut Poison Control Center; all other carbon monoxide–related calls were due to storm-related exposures. We hypothesized that there would be significant differences between the two storm populations with regard to the sources of exposure, mean carboxyhemoglobin concentrations, and timing of carbon monoxide–related calls to the Connecticut Poison Control Center.

Descriptive data were collected for all identified cases, including reported exposure date, patient age and gender, exposure source, presenting symptoms, whether hospitalization was required, carboxyhemoglobin concentration (if obtained), and provided treatment (normobaric 100% oxygen, hyperbaric oxygen, and other treatments). Hospitalization was defined as either an emergency department presentation or inpatient hospital admission. Collected data were logged into a Microsoft Excel spreadsheet database (Microsoft Corporation, Redmond WA).

Mann–Whitney tests were used for analysis of patient ages and carboxyhemoglobin concentrations, which were not normally distributed; median values and interquartile ranges (IQRs) were reported for these results. Categorical variables were analyzed with chi-square or Fisher's exact tests, as appropriate. ORs or Haldane corrected ORs with 95% CIs were reported for categorical variables; the Haldane OR involves the addition of 0.5 to each cell of an OR calculation to allow a finite OR determination when one of the cell values is zero.[10] Statistical analysis was performed using Stata, version 11 (Stata Statistical Software 2009, StataCorp, College Station TX).