Predictable, Preventable, and Deadly: Epidemic Carbon Monoxide Poisoning After Storms

The nor'easter storms of March 2018 brought particularly harsh weather conditions to the northeastern United States, with four major storm systems in one month. As medical toxicologists in the affected area, practicing at university hospitals affiliated with regional poison control centers, we were deeply saddened knowing that, once again, we'd be tallying storm-related poisonings from carbon monoxide (CO), offering consultation to area physicians via our poison centers, and caring for patients with serious exposures presenting to our own institutions.

STORM-ASSOCIATED CARBON MONOXIDE POISONING

Severe winter storms associated with heavy snow and strong winds often result in widespread and prolonged power outages, interrupting essential household functions including home heating. Similar power losses occur after major summer storms, such as hurricanes and tornadoes, compromising food refrigeration and home cooling afforded by fans and air conditioners. In both scenarios, residents may turn to dangerous remedies for the absent electric power, including use of indoor charcoal grills and camp stoves for cooking or heating and, in particular, inappropriate placement of portable gasoline-powered generators.[1] Such portable generators utilize combustion engines that historically emit large quantities of CO, estimated by staff at the US Consumer Product Safety Commission (CPSC) to approximate that of more than 400 idling late-model automobiles.[2]

Unfortunately, poison control centers continue to see surges in generator-associated CO poisoning with major storms, despite warning labels mandated by the CPSC in 2006 and repeated public health advisories. These cases arise primarily when a generator is used too close to or inside the home, including in an attached garage or porch. CO can also enter the home if the generator is operated outside but close enough to allow convection to carry fumes inside. Further confusion results from additional labels on the generators instructing consumers not to get the engine wet, although they are often most likely to be used in wet, torrential weather conditions.

Predictably, tragedies result. Whole households are poisoned, some fatally. Poison control centers nationwide conduct surveillance on these exposures and regularly detect a poststorm increase in such cases. After Superstorm Sandy in October 2012, eight poison centers from the affected area and the Centers for Disease Control and Prevention reported a total of 263 storm-related CO exposures, including four fatal cases from Pennsylvania.[3] CPSC staff estimate that over 650 deaths and 25 000 injuries from such exposures occurred between 2004 and 2012.[2]

From March 1 to 28, 2018, a total 100 CO exposures were reported to our three poison centers, serving Philadelphia, eastern Pennsylvania, and Delaware; New Jersey; and Massachusetts and Rhode Island. Of these, 43 (43%) were caused by portable generator exhaust, resulting in several critically ill patients and one death. Inappropriate generator placement was again noted, including in a basement, near a garage door, and outside but close to a crawl space in the home.

CARBON MONOXIDE TOXICOLOGY

CO is a colorless, odorless byproduct of combustion that seeps into enclosed spaces and can kill quickly in high concentrations. Common sources also include home heating malfunctions, chimney obstructions, house fires, and automobile exhaust. At toxic doses, CO is a frequent cause of poisoning morbidity and death in the United States, and results in more than 50 000 emergency department visits each year.[4] CO's major toxic effects include (1) binding to hemoglobin to form carboxyhemoglobin and shifting the oxyhemoglobin-dissociation curve to the left (both of which decrease tissue oxygen delivery) and (2) inhibiting mitochondrial cytochrome oxidase. These effects result in acute cellular hypoxia and potentially cause hypoxic injury of the brain, heart, and other organs. Later posthypoxic injuries—particularly delayed neurocognitive sequelae—are believed to be caused by multiple additional inflammatory and immunological effects, as noted in various experimental models. Acute symptoms are nonspecific and, when mild, may mimic an afebrile viral syndrome. The most common include headache, dizziness, nausea, vomiting, confusion, fatigue, chest pain, dyspnea, and loss of consciousness. More severe exposures may result in seizures, coma, brain and myocardial infarction, and death. Diagnosis is based on the triad of suspicious exposure history, clinical symptoms, and elevated carboxyhemoglobin level, although the latter may be low after significant elapsed time from exposure or oxygen therapy. Fetuses, young children (with higher minute ventilation and metabolic rates), and older adults (especially with coronary artery disease) are particularly vulnerable to CO

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STRATEGIES TO MAKE PORTABLE GENERATOR USE SAFER

Strategy (Rationale or Comment)
CO detectors paired with every generator at time of purchase. (Heightened awareness at time of use and convenience to implement; would have benefits for protection from other sources of CO.)
Attached longer cords to enable placement at a safe distance. (Heightened awareness at time of use and convenience to implement.)
Low CO emission generators.[a] (Technology currently available to reduce CO emissions by 90% or more; likely greatest overall impact on decreasing morbidity and mortality.)
Automatic shutoff systems.[a] (Technology currently available, may reduce hazard if generator is placed inappropriately in an enclosed space; however, CO concentration at site of generator may be significantly lower than that in living quarters.)

Note. CO = carbon monoxide.

[a]Both of these features are required to meet current ANSI/UL 2201 standard, announced January 2018 (https://www.ul.com/portablegenerators).

poisoning. Initial treatment priorities are elimination of the CO exposure and provision of 100% oxygen. Further therapy with hyperbaric oxygen in select cases is dependent on availability, and somewhat controversial, but it may be associated with lessened neurocognitive sequelae. We agree with many experts who recommend such treatment of patients with loss of consciousness, ischemic cardiac changes, neurological deficits, significant metabolic acidosis, or carboxyhemoglobin greater than 25%.[4]

POTENTIAL SOLUTIONS

Safeguards must be put in place to prevent such tragic CO poisoning events from improper use of generators occurring with every major storm (the box on this page). Poison centers have long prioritized poisoning prevention, and they recognize from long experience that poisoning prevention depends far more on making safer products (e.g., child-resistant medication caps, less concentrated drain cleaners) than on education alone. To date, generator warning labels and repeated health advisories have not been effective. Increasing our efforts at education and outreach may still be of some benefit, especially for the millions of families who already own existing generator models.[1] Enactment of policies to mandate and facilitate the installation and maintenance of battery-operated CO detectors in every home, particularly in bedrooms and other areas where they would wake sleeping family members, should be an all-season public health priority, and especially emphasized with seasonal storm warnings.

Some engineering strategies proposed to make generators safer include attaching longer cords connecting the generator to the home and installing shutoff systems. However, the ultimate cure for this generator-associated epidemic likely resides in producing generators with greatly reduced CO emissions.[2] Unintentional CO poisoning due to automobile exhaust decreased dramatically with the advent of technological advances (e.g., electronic fuel injection and catalytic converters) that greatly lowered exhaust CO emissions from automobile engines.[5] This same technology now exists to affordably manufacture generators that emit far less CO, and such generators have recently become commercially available. Legislative and advocacy efforts to regulate CO emissions requirements on portable generator engines have been ongoing for years, with little progress. In 2016, the CPSC proposed a rule to mandate low-emission portable generators, but this regulation has not yet been enacted.[2] Until it is, we can advocate for manufacturers and retailers to voluntarily produce and sell only such safer generators.

CONCLUSION

"Knowing is not enough; we must apply," the axiom widely attributed to Goethe, certainly applies to this quagmire. We know enough about the epidemiology of storms, portable generators, and CO poisonings. We still need enhanced education to warn the public about sources of CO, and outreach to achieve the universal placement and proper use of CO detectors in every American home. These efforts would mitigate morbidity due to all causes of CO exposure. Going forward, newer, far safer generators are available and should be mandated. The time for action toward eliminating these entirely predictable, completely preventable, but often deadly exposures is now, before the next storm. AJPH

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REFERENCES

1. Iqbal S, Clower JH, Hernandez SA, Damon SA, Yip FY. A review of disaster-related carbon monoxide poisoning: surveillance, epidemiology and opportunities for prevention. *Am J Public Health*. 2012;102(10):1957–1963.

2. Buyer J. Portable generators and carbon monoxide poisoning. Available at: https://www.cpsc.gov/s3fs-public/PresentationSAE_SETC.pdf. Accessed April 11, 2018.

3. Centers for Disease Control and Prevention. Notes from the field: carbon monoxide exposures reported to poison centers and related to Hurricane Sandy—northeastern United States, 2012. *MMWR Morb Mortal Wkly Rep*. 2012;61(44):905.

4. Weaver LK. Carbon monoxide poisoning. *N Engl J Med*. 2009;360(12):1217–1225.

5. Mott JA, Wolfe MI, Alverson CJ, et al. National vehicle emissions policies and practices and declining US carbon monoxide—related mortality. *JAMA*. 2002; 288(8):988–995.