Carbon Monoxide Poisoning in Children: Guidance for Disaster Events

Disaster events such as hurricanes, earthquakes, and snow storms often lead to electrical power losses, searches for alternative ways to heat, cook, or power homes, and use of gas-powered equipment and tools. Carbon monoxide poisoning is, therefore, a predictable public health hazard during disaster events. This document provides basic guidance for health care providers to assist with the recognition, initial management, and prevention of carbon monoxide poisoning. A final section titled "Important carbon monoxide poisoning prevention tips" is suitable for families.

What is Carbon Monoxide?

Carbon monoxide (CO) is a toxic, colorless, odorless, and tasteless gas that is a product of the burning fuels such as firewood, charcoal, gasoline, and natural gas. Carbon monoxide can quickly build up to unsafe levels in enclosed or semi-enclosed areas, leading to death within minutes; carbon monoxide can enter living spaces through windows or vents. It is a notorious cause of unintentional poison-related death in the United States, responsible for approximately 450 deaths every year between 1999-2004 (*MMWR* 2007). CO poisoning is also a predictable cause of mortality and morbidity in post-disaster situations, when widespread power outages occur (*MMWR* 2012).

Infants and children have an increased susceptibility to CO toxicity because of their higher metabolic rates. The CDC reported that in the United States in 2001-2003, children younger than 4 years had the highest incidence of unintentional CO exposure (*MMWR* 2005). Exposed children often become symptomatic earlier, and recover faster, than similarly exposed adults since they have lower blood volumes and higher minute ventilation (AAP 2011).

What are the symptoms of CO poisoning?

Symptoms of CO poisoning are variable and non-specific. Early symptoms include headache, dizziness, weakness, drowsiness, nausea, and vomiting. Often these early symptoms resemble those of a 'flu-like' syndrome and can be misdiagnosed as a viral infection or food poisoning. Other symptoms and signs of more severe, life-threatening CO poisoning can include skin pallor, dyspnea on exertion, palpitations, confusion, poor mentation, irritability, irrational behavior, slurred speech, loss of consciousness, coma, severe acidosis, and death (AAP 2011). Acute exposure to CO levels greater than 800 parts per million (ppm) can rapidly cause brain injury, cerebral edema, coma, and death.

Other indoor air pollutants may also cause several of the symptoms attributable to CO, such as tobacco smoke and other indoor air pollutants. However, exposure to CO does not irritate the eyes and lungs, which are characteristics of tobacco smoke, volatile organic compounds, and allergens. Important points to identify in the history include lack of fever associated with symptoms, the history of exposure, as well as multiple patients having a similar constellation of symptoms.

The clinical presentation of CO poisoning is the result of its underlying systemic toxicity. Its effects are caused not only by impaired oxygen delivery, but also by disrupting oxygen utilization and respiration at the cellular

level, and by promoting an inflammatory response, particularly in high-oxygen demand organs such as the heart and brain (AAP 2011). Severity of symptoms ranges from mild to very severe (coma, respiratory depression).

Delayed neuropsychological sequelae can occur as early as 24 hours after an acute, severe CO exposure, resulting in impaired executive functioning, personality changes, and psychosis (AAP 2011). Those with significant exposure to CO may undergo severe neuropsychiatric deterioration, called delayed-type encephalopathy, which follows months of apparent normal neurological functioning (Vieregge *et. al.,* 1989). The incidence of long-term CO exposure is unknown. There are no data that show that low-level longer term CO exposure (24 hours up to years) without acute symptoms leads to long-term neuropsychiatric sequelae (AAP 2011).

Symptoms of chronic poisoning at a higher level of exposure can include chronic fatigue, affective conditions and emotional distress, memory deficits, difficulty working, sleep disturbances, vertigo, neuropathy, paresthesias, recurrent infections, polycythemia, abdominal pain, and diarrhea (Weaver 2009). Recent radiological studies using magnetic resonance imaging has shown severe CO intoxication can lead to persistent cerebral pathological changes including damage to the globus pallidus, hippocampus, cerebellum, white matter, and other structures independent of chronic CO neurological signs (Durak *et. al.,* 2005).

CO poisoning in pregnancy

In utero, CO readily crosses the placenta. With fetal hemoglobin having a higher affinity for CO than oxygen (240 times) and the CO elimination taking longer in the fetal circulation compared to maternal circulation, fetal hypoxia may ensue, potentially resulting in permanent fetal brain damage and stillbirth at high maternal CO exposures (Koren *et. al*., 1991). Prenatal CO exposure has been shown to result in decreased birth weight, small infant head circumference, behavioral abnormalities, and disruption in cognitive function (Gomez *et. al.*, 2005).

What are the sources of CO in a disaster setting?

The use of alternative sources of fuel or electricity for heating, cooling, cooking, or generation of electricity can cause CO to build up in a home, garage, or camper. Even if a generator is placed outdoors but near an open window, door or other opening where exhaust can enter the building, dangerous exposure can occur. Automobiles being "warmed-up" in enclosed spaces such as garages, or exhaust pipes plugged with snow or mud can also result in carbon monoxide exposure. As a result, people can become exposed to toxic levels in short duration of time.

Common sources of CO include the following:

- Furnaces, fireplaces, and wood stoves
- Gas stoves
- Hot water heaters (gas)
- Portable generators
- Gas and charcoal grills
- Automobiles / trucks
- Kerosene / portable heaters
- Chainsaws
- Pressure washers and gas-powered tools

Evaluation of suspected CO poisoning

- Diagnosis is based on a suggestive history and physical findings coupled with confirmatory testing. Patients with significant carboxyhemoglobin levels can have normal readings on a regular pulse oximeter. Confirmatory methods include direct measurement of blood carboxyhemoglobin or measurement of carboxyhemoglobin using a transcutaneous coximeter capable of specifically measuring carboxyhemoglobin. Normal carboxyhemoglobin levels in non-smokers can range from 1-2%, while in cigarette smokers, they can range from 5-10% (Turner, 1986, Stewart, 1974). The half-life of carboxyhemoglobin when breathing room air is about 4 hours, and when on oxygen a shorter time, so measured levels must be interpreted accordingly. Patients should be examined for other conditions, including smoke inhalation, trauma, medical illness, or intoxication.
- Neurological exam should include an assessment of age-appropriate cognitive function, such as a mini-mental status exam.
- **If it is suspected that a child has been poisoned by carbon monoxide:**
  - Move the child to a place with fresh air immediately.
  - Administer supplemental oxygen using highest amount possible (if available).
  - Get child to an emergency department and tell them that you suspect carbon monoxide poisoning.
  - Consultation with a poison control center (1-800-222-1222), or with a physician with expertise in managing carbon monoxide poisoning and familiar with all treatment options is recommended.

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Important carbon monoxide (CO) poisoning prevention tips (PATIENT FACTSHEET)

Have a working smoke detector and CO detector in the home.

It is suggested that CO detectors:

- be installed near every sleeping area of the home,
- be tested weekly,
- be cleaned monthly,
- have battery replaced yearly,
- be replaced every 7 years.

Have home heating systems checked by a trained professional each year. Make sure that furnaces and gas fireplaces are properly vented and that there are no obstructions to the exhaust pipe. Hot water heaters can also be sources of carbon monoxide. Make sure that they are installed according to manufacturer's specifications and are properly vented.

Make sure that wood stoves and fireplace chimneys are cleaned and are in compliance with all state and local regulations for installation and proper ventilation of exhausts before they are put in use and are maintained without obstruction, including snow.

Never use a gas range or oven to heat a home.

Never use a charcoal grill, hibachi grill, lantern, or portable camping stove inside a home, tent or camper. Never use gas or kerosene heaters indoors that don't have a vent to outside.

Never run a generator, pressure washer, or any gasoline-powered engine inside a basement, garage, or other enclosed structure (CO may build up even if the doors or windows are open). Keep vents and flues free of trash, especially if winds are high. Flying trash can block ventilation lines.

Run any motor vehicle, generator, pressure washer, or any gasoline-powered engine outside at least 15 feet from any open window, door, or vent where exhaust can drift into an enclosed area. Since wind may still blow CO into home, make sure to have CO detector in the home.

Never leave the motor running in a car/vehicle parked in a closed or partially closed space, such as a garage. Make sure that car exhaust pipes are clear of snow or mud so fumes will not go back into the vehicle.

For power outages, it is safest to use permanently-installed generators instead of portable generators. The only advised method to connect a generator to house wiring is by having a qualified electrician install a power transfer switch. For further information on the safe use of generators during a power outage see: http://www.doh.wa.gov/Emergencies/EmergencyPreparednessandResponse/Factsheets/GeneratorUseDuringaPowerOutage.aspx

If conditions are too hot or too cold during a disaster or power outage, go stay with friends or at a community shelter. If carbon monoxide poisoning is suspected, take people affected to fresh air and call 911 for assistance. Make sure other people in the same area are safe. Go to emergency room for care.

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