Carbon Monoxide... The Silent Killer

Physician Focus Series
Winter is upon us. As use of home heating hits its peak,1 it’s a critical time to be aware of carbon monoxide poisoning. Heating systems and home appliances can malfunction even in mild winter temperatures. Winter ice storms, blizzards, and deep freezes can cause loss of power for extended periods, leading to the need for gasoline-powered generators or tools, and cooking with charcoal or gas grills. Many people are sickened or killed due to carbon monoxide exposure when such devices, which are designed to be used only outdoors, are used inside or near homes.2 These exposures are preventable. And when they do occur, taking quick action can save lives.

The Silent Threat
Carbon monoxide (CO) is known as the silent killer for good reason. It is an odorless, colorless, poisonous gas that often goes undetected.1 CO can cause sudden illness and death when present in sufficient concentrations in ambient air.1 Symptoms of CO poisoning are variable and nonspecific.3 When mild symptoms are mistaken for “the flu,”1 affected individuals may not be aware that a home appliance or heating furnace could be malfunctioning. The tragic result all too often is preventable death. People go to bed thinking they are fighting “the flu,” and never wake up.

Clinical presentation results from underlying systemic toxicity. Effects are caused by impaired oxygen delivery as well as disruption of oxygen utilization and respiration at the cellular level. This is particularly the case for organs such as the heart and brain, in which oxygen is in high demand.3 CO produces hypoxia by binding with hemoglobin to form carboxyhemoglobin, with a leftward shift of the oxyhemoglobin dissociation curve, and binding to heme-containing proteins.4 CO has an affinity for hemoglobin that is over 200 times higher than that of oxygen.4 Other mechanisms of CO toxicity include direct cellular toxicity and increased nitric oxide activity leading to free radical formation and brain lipid peroxidation.5 CO toxicity-related brain lipid peroxidation involves a posts ischemic reperfusion phenomenon, mediated by alterations in cerebral blood flow and oxidative free radical damage, which may be responsible for the clinical syndrome of delayed neurologic sequelae.5 It is estimated that CO poisoning results in approximately 50,000 emergency department visits annually in the United States.6 Mortality rate ranges from 1% to 3%.6 Each year in the United States, more than 400 people die from accidental CO poisoning.7 Portable generators alone resulted in over 800 accidental deaths due to CO between 1999 and 2012.8 Many survivors of CO poisoning suffer from long-term neurologic and affective impacts. For example, long-term neurocognitive deficits occur in 15% to 40% of patients, and approximately one-third of patients with moderate to severe poisoning experience cardiac effects.6 Populations at particular risk include pregnant women, infants, the elderly, and those with anemia, chronic heart disease, or respiratory illness.3 CO is produced primarily as a result of incomplete combustion of any carbonaceous fuel (gasoline, propane, natural gas, or charcoal) by various types of equipment and appliances3,5 including generators, lanterns, natural gas-powered devices, stoves, dryers, water heaters, fireplaces, furnaces, small engines, gasoline-powered tools (eg, power washers), burning fuel in cars, trucks, and boats, or when cooking on charcoal or gas grills.1-3 When used appropriately and vented properly, appliances, heating furnaces, and fireplaces intended for use inside the home are safe, unless there is a malfunction. Equipment not intended for use inside the home should not be brought inside. When the heat stops working, bringing a kerosene camping stove inside can prove deadly.
An Ounce of Prevention

Prevention of CO poisoning is worth its weight in gold. Education is critical; simple miscalculations can lead to costly outcomes. Preparedness plans for any disaster scenario should always address the potential for CO poisoning.

The simplest and most critical measure any homeowner can take to help avoid CO poisoning is to install battery-operated CO detectors/alarms or plug-in CO detectors/alarms with battery back-up in their homes, following manufacturer instructions. It is vital that CO detectors/alarms be tested frequently and batteries be replaced regularly. It is recommended they be checked each spring and fall when changing the time on your clocks, and replaced every five years. Every home should have at least one functioning CO detector/alarm; ideally, a detector/alarm is placed in a hallway near each separate sleeping area.

- In the event of a CO alarm sounding, never ignore the alarm, and do not try to find the source of the gas. Immediately move outside for fresh air, call 911, account for all occupants, and await clearance from first responders before re-entering the home.
- NEVER use a generator or other gasoline-powered engine inside a home, garage, basement, crawl space, tent, camper, or other even partially enclosed area. Place generators and similar equipment in a well-ventilated outdoor area at least 20 feet away from any home or structure, and away from doors, windows, vents, and air conditioning units that might allow CO to enter the home. Some resources recommend placing generators at least 25 feet away from the home or other nearby dwellings.
- Do not use grills (gas or charcoal) inside a house, garage, vehicle, tent, camper, or fireplace.
- Do not use a lantern or portable camping stove inside a home, tent, or camper.
- Do not use gas ovens or ranges for heating a home.
- Do not use portable flameless chemical heaters indoors.
- NEVER run a car in a garage attached to a house, even with the garage door open.
- Furnaces, water heaters, and other gas or coal-burning appliances, as well as chimneys, should be serviced by a qualified technician annually.
- If you begin to feel ill – including dizziness or weakness – while using a generator or similar device, get to fresh air without delay. It could save your life.
- If CO poisoning is suspected, call 911 or the Poison Control Center (1-800-222-1222) immediately.

Diagnostic Approach

A diagnosis of CO poisoning is suggested by:
- Symptoms consistent with CO poisoning
- History of recent CO exposure
- Elevated carboxyhemoglobin level

However, these are not strict criteria. Use caution to avoid dismissing cases of potential chronic, lower-level CO poisoning. Some patients may be discovered unconscious or severely ill, making a history difficult or impossible to obtain.

Symptoms of CO poisoning are variable and nonspecific. Mild symptoms can be mistaken for “the flu,” especially as many in the family may suffer. Symptoms can include dizziness, weakness, fatigue, chest pain (especially in those with heart disease), shortness of breath, nausea, vomiting, headaches, confusion, lack of coordination, impaired vision, and loss of consciousness. No single symptom is either sensitive or specific for CO poisoning. As animals have a higher metabolic rate, they are often the first to get ill, so a sick dog or cat may be a warning for the family.

Severe, acute CO poisoning presents with cognitive dysfunction, which can progress rapidly. Cardiac effects can include myocardial infarction, arrhythmia, and left ventricular systolic dysfunction. Long-term neurocognitive effects include impaired memory, cognitive dysfunction, depression, anxiety, and/or vestibular and motor deficits.
The clinical syndrome of delayed neurologic sequelae involves apparent recovery from acute CO poisoning, followed by neurologic and behavioral deterioration after a period of 2 to 40 days. This syndrome can result in almost any neurologic or psychiatric symptom. It occurs more commonly in patients who suffered a comatose state as a result of toxicity, older patients, and possibly those patients with prolonged exposure.

Serum carboxyhemoglobin levels of 2% in nonsmokers and greater than 9% in smokers strongly support a diagnosis of CO poisoning. Neuroimaging (CT or MRI) can be considered to exclude other causes of loss of consciousness or abnormal neurologic symptoms or signs. In addition, certain patterns of brain injury (eg, necrosis of the globus pallidus region and other abnormalities of the basal ganglia) are characteristic of CO poisoning and may correlate with prognosis. Chest radiography should be performed in all patients with severe CO poisoning (eg, loss of consciousness, cardiorespiratory signs or symptoms). Chest radiograph may show noncardiogenic pulmonary edema in these patients. ECG should be performed in patients with severe CO poisoning or in those who have cardiac symptoms. Consider measuring serum troponin levels in patients with severe CO poisoning, to assess for myocardial injury. Pregnancy testing is recommended in women of childbearing age because of increased CO risk to the fetus.

Keep in mind that CO poisoning is easily misdiagnosed in the absence of a clear exposure history; maintain a high index of suspicion during winter months and in the context of recent natural disasters and severe weather, when exposure may be more likely. Other clues that may point toward CO exposure include symptoms reported in family pets, multiple family members experiencing similar symptoms, and symptoms that improve upon removal from the exposure environment.

Treatment

Appropriate and timely treatment of CO poisoning is critical for minimizing morbidity and mortality. High-flow normobaric oxygen should be administered at 100% to all patients presenting with CO poisoning and continued until carboxyhemoglobin levels have normalized (usually less than 3%) and symptoms have resolved (usually 4-6 hours). Supportive care, including airway management and hemodynamic stabilization, should be provided.

Hyperbaric oxygen therapy will remove CO from the blood at a faster rate than normobaric oxygen and has shown a reversal effect for inflammation and mitochondrial dysfunction related to CO poisoning. Not all studies have reported an overall benefit from hyperbaric oxygen therapy, but study quality has varied. Hyperbaric oxygen therapy can be considered in the following circumstances:

- Carboxyhemoglobin level 25% or higher
- Loss of consciousness or coma
- Cardiac involvement
- Severe acidosis
- Neurologic deficits
- Abnormal neuropsychiatric testing
- Age 36 years or older
- Seizures

Hyperbaric oxygen can also be considered for patients with a carboxyhemoglobin level less than 25% if clinical condition or exposure history warrants it. Hyperbaric oxygen therapy is the treatment of choice for pregnant women, even with less severe poisoning. Patients should be treated in consultation with a medical toxicologist.

All patients should be informed about the potential for delayed neurologic complications and given instructions on what to do if these occur. Provide follow-up at two weeks to two months to assess for delayed neuropsychiatric sequelae.

Patient outcomes depend on the concentration of CO, duration of exposure, and underlying health status of the patient. Poorer prognosis is seen with higher carboxyhemoglobin levels, elderly patients, patients with preexisting cardiovascular disease, CO-induced metabolic acidosis, or structural changes on neuroimaging.
Final Thoughts

Winter is prime time for CO poisoning.\textsuperscript{1} Malfunctioning furnaces and home appliances can be an unexpected source of CO in the home. Ice storms and blizzards can cause extended power outages, resulting in increased use of generators and other equipment powered by fossil fuels. Tragic accidents can occur when this equipment is used improperly. Fortunately, the morbidity and mortality associated with CO poisoning is utterly preventable with proper patient education and public health messaging.\textsuperscript{14,15}

When CO exposure does occur, rapid response to remove exposed persons from the impacted environment is critical and may save lives.

Contacting 911, a medical toxicologist, or the Poison Control Center (1-800-222-1222) for anyone exhibiting symptoms is critical. For those suffering from CO poisoning, accurate diagnosis and urgent treatment response is of paramount importance to reduce morbidity and mortality.

The avoidance of carbon monoxide – the silent killer – can ensure that a preventable exposure does not result in tragic consequences. A carbon monoxide detector, while not captivating, may be the perfect holiday gift.

For more information, see the Carbon Monoxide Toxicity Clinical Overview in ClinicalKey.

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References


