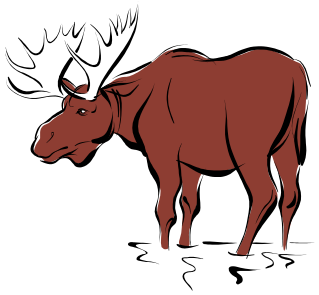


Northern Exposures

The regional newsletter devoted to enhancing the management of and improving health outcomes for poisoned patients.

Northern New England Poison Center

Issue 2, October 2007

Carbon Monoxide Poisoning: "The Invisible Killer"

Cases:

1. Two house occupants are found by a neighbor in the morning, one lying still on the kitchen floor while the other is still in bed under the covers. No odors are noted in the house. EMS transports both victims to the hospital where they are pronounced dead. The neighbor states that months back the power company had disconnected service for unpaid bills. Despite knowledge of the dangers of carbon monoxide, the home owner felt it safe to use a gas generator in the basement to provide heat with a small window open beside it for venting.

2. Three subcontractors performing warehouse jobs present to the ED with nausea, headache and flu symptoms. In the ED all had felt well before today. Several propane-powered forklifts were being used to move pallets of building materials. The workers had been instructed to wear N-95 masks to protect them against the fumes. In the ED all three men are placed on oxygen for four hours. Carbon monoxide levels range from 15-25% upon arrival. Two of the three become asymptomatic however the third has persistent headache and scores surprisingly only a 23/30 on a standardized mini-mental status exam. He is transferred to an HBO facility for a three dive protocol. There is a concern that another co-worker who left work earlier with symptoms is now unreachable.

Public Health Problem[1-5]

CO is one of the leading causes of unintentional poisoning deaths in the United States. CO poisoning is more common during winter months but can occur anytime. Men and the elderly have higher rates of death. According to the Center for Disease Control (CDC) there are approximately 3,800 deaths from fires or other sources of carbon monoxide each year. Of these, 2,400 are intentional or suicides. An estimated 500 non-fire-related, unintentional CO deaths occur each year, 200 of which are from CO produced by fuel-burning appliances.

Public Health Problem, continued on page 2

3. A young couple presents to the ED with headache upon awakening in the morning. The woman had gotten up to take a shower but had passed out while in the shower. She was uninjured but is concerned because she is three months pregnant. Her fiancé has less severe symptoms. The woman's carbon monoxide level after 1 hour of oxygen is 15%. The fire department is dispatched to the scene where they detect high levels in the apartment and the furnace is red-tagged. They find next-door neighbors, one of whom has a history of angina, complaining of chest pain. Our patient is fearful of the adverse effects hyperbaric treatments may have on her fetus but consents to treatment.

Public Health Problem, continued from page 1

Common scenarios include:

- burning charcoal inside a home, garage, vehicle or tent;
- running cars in attached garages
- using portable generators indoors or partially-enclosed spaces.

In 2006, the NNEPC handled roughly 200 CO exposures. Most of these exposures occurred during October through March.

There are approximately 50,000 Emergency Room visits of non-fatal acute CO poisoning each year. Significant underreporting is a concern. One study estimates the rate of missed diagnosis to be as high as 30%.

Automobile-related CO exposures have declined 80% since 1975 due to catalytic converter reduced CO emissions. The catalytic converter does not protect against CO poisoning when the tailpipe is obstructed. For example, a car stuck in a snow drift kept running for heat may expose the occupant to dangerous exhaust.

Underlying Mechanisms[6-9]

Carbon monoxide (CO) is a colorless, odorless, tasteless, non-irritating, poisonous gas produced by the incomplete combustion of carbon-containing fuels such as propane and gasoline. Its presence is undetectable until the insidious onset of symptoms without a working CO (not smoke) alarm.

Toxicity is mainly a result of impaired oxygen transport with subsequent hypoxia and ischemia. Sites of binding include hemoglobin, myoglobin (including the muscle you are using right now – the heart) and mitochondrial enzyme cytochrome oxidase.

CO competes with oxygen (O2) for binding sites on the heme portion of the hemoglobin (HgB) molecules in red blood cells to form carboxyhemoglobin (COHb). CO binds with an affinity 250 times greater than that of oxygen resulting in accumulation of COHb at relatively paltry concentrations of CO (8% COHb at OSHA limit 50 ppm or 0.005%, 14% COHb at 100 ppm)).

CO shifts the oxygen-hemoglobin dissociation curve to the left, diminishing the off-loading of the remaining oxygen to progressively hypoxic tissues. Most of the adverse health effects of CO stem from its ability to reduce oxygen delivery to vital organs with high oxygen consumption such as the heart and the central nervous system (CNS).

CO may additionally induce brain injury by activating an inflammatory cascade resulting in neuronal damage. CO mimics nitric oxide (NO), an endogenous messenger released by endothelium, resulting in vasodilatation (syncope) and loss of cerebral blood flow. If not quickly reversed this leads to rapid death.

A gradual dissociation of the COHb complex occurs once a patient has been removed from the source of exposure with an elimination half-life of 5-6 hours (e.g., exposure up to 30% COHb would be normal or less than 5% in 15 hours). The half-life is reduced with high-flow oxygen to approximately 1 hour (30% COHb back to normal in <4 hours). Hyperbaric oxygen therapy can further reduce the half life to 20 minutes but HBO is not used to alleviate acute hypoxia.

Practical Prevention

Carbon monoxide poisonings are common and can be fatal. Every home should have a working carbon monoxide alarm. At least one alarm should be installed close to sleeping areas. Consider placing extra alarms on every level and in every bedroom of a home for more protection. These may be hard-wired but should contain battery back-up power in case of a power outage. Smoke detectors will not detect CO and vice versa.

First Response

When the call comes in from someone whose CO alarm has gone off, the first advice is for all persons and pets to get out of the home or business immediately. CO alarms have been proven to save lives and reduce the severity of exposure. CO poisoning symptoms are commonly overlooked.

When patients are experiencing unexplained symptoms of nausea, confusion, headache, fatigue and general malaise a high index of suspicion for CO poisoning should be maintained. Scene CO levels can easily be measured by most fire departments and should be done before entering any enclosed dwelling.

When responding to the scene of suspected CO poisoning, EMS/Fire should not enter the building without proper personal protection including their own air supply (SCBA). The first priority after scene safety is to remove patients from the exposure to fresh air immediately and provide oxygen by mask. Any patient with any potential CO exposure should be transported to the nearest medical facility. Concurrent trauma can occur thus standard spinal precautions should be maintained.

Helpful questions to ask include:

- Describe your heating system. When was it last serviced?
- Did your symptoms coincide with your furnace usage?
- Are there appliances that use fossil fuels running indoors? Are there attached structures where this may be going on?
- Are other people in the home/business complaining of the same symptoms simultaneously? Are pets affected?
- Do you have a working CO detector?

Storm-Related CO Poisoning Prevention: Lessons Learned[10-11]

Over the past 15 years, numerous CO poisoning epidemics have been reported in the United States. Researchers have reviewed these epidemics and possible prevention lessons:

- The major sources of CO responsible for poisonings can be related to the type of storm and are predictable.
- Campaigns to educate the public about risks for CO exposure should be timed regionally to coincide with the peak risk for typical storms.
- Opportunities exist to teach prevention strategies against generator-related CO poisonings from loss of electrical power.
- There is a window of time for effective communications regarding the dangers of CO poisoning even after a storm strikes.

CO poisoning can be prevented with preparation!

Symptoms[6-9]

Individual manifestations of symptoms vary greatly with COHb levels. Rough correlations can be seen particularly at higher concentrations (>25%) between COHb levels and severity of symptoms.

The most common initial symptoms are vague progressive neurological and constitutional ones. Minor exposures may result in “flu-like” symptoms such as headaches (the most common symptom), dizziness/lightheadedness, nausea and fatigue. Patients may experience chest pain or breathlessness mimicking their angina. Vomiting is common.

Symptoms continued on page 4

Symptoms continued from page 3

Moderate to severe toxicity may result in severe headaches, weakness and cerebellar signs such as ataxia. Initial anxious tachycardia and tachypnea may be followed by syncope or progressively impaired mental functioning (slowed thinking, difficulty concentrating, memory loss, etc.); cardiac dysrhythmias; hypotension; convulsions; coma; and death.[1-4]

Persistent and delayed neurological deficits from CO toxicity include: delirium, memory loss, psychosis, parkinsonism and other movement disorders, personality/behavioral changes, paralysis, peripheral neuropathies and incontinence.

Assessment and Management[14-19]

The assessment of patients begins with a high degree of suspicion for CO poisoning in light of a non-specific toxidrome that can be misinterpreted as flu-like. In the absence of a confirmed exposure by scene air sampling, a co-oximeter measured carboxyhemoglobin level (multiple wavelength infrared detection) is the gold-standard. Transcutaneous specific CO detectors are gaining popularity while standard pulse oximetry (two wavelength IR) will fail to detect saturation changes until CO levels are very high.

Carbon monoxide alarms have been proven to save lives and reduce toxicity. It is essential to educate patients on the proper positioning and maintenance of home CO alarms to prevent future poisonings. Patients should be told to have at least one working CO alarm near the sleeping area. Batteries should be checked twice a year when clocks are changed for daylight savings time. CO alarms are manufactured under Underwriter's Laboratory (UL 2034) guidelines to sound when air concentrations over a specified time period would result in a COHb level of at least 10%. This is beyond levels expected by poor urban air quality (up to 15-30 ppm) or from smoking (each 1 pack per day (ppd) tobacco equals 3% rise in COHb).

Nursing Evaluation[12-13]

While awaiting results of a carboxyhemoglobin (COHb) level by transcutaneous measurement (Masimo®) or venopuncture (extended VBG or ABG) the patient should be continued on high-flow oxygen delivered via non-rebreather mask (providing 70-90% oxygen), positive-pressure mask or endotracheal tube if needed. The end-point of oxygen therapy is resolution of symptoms and an expected COHb level less than 5% (calculated from the initial level and expected 1 hour elimination half-life while on 100% oxygen). Repeated blood gases are unnecessary. It is important to realize that cutaneous "pulse ox" oxygen saturation readings may be surprisingly normal. Standard blood gas testing may not include COHb unless specifically requested.

The pregnant patients are treated the same manner as other CO-poisoned patients with the addition of continuous fetal monitoring to evaluate for fetal distress (decelerations).

Children and the elderly may be more prone to CO toxicity than young adults due to difficulty in the ability to assess baseline mental capabilities, co-morbidities and decreased functional reserve. Fetal Hb concentrations may falsely elevate COHb in infants. Patients may not recognize their deficits and thus pose a safety risk while in the department.

Assessment and Management continued on page 5

Assessment and Management continued from page 4

Important historical elements should include the likely source of carbon monoxide, duration of exposure and the identification of all possible victims. A complete health inventory may not be possible due to decreased mental ability capacity. CNS symptoms may vary from subtle cognitive deficits not apparent during casual conversation to coma. Headache may also distract patients from other concerns such as chest pain or breathlessness due to possible cardiac ischemia.

Carbon monoxide exposure may occur in a home or workplace cluster resulting in the need to prioritize victims. Those found in cardiac arrest have an extremely poor prognosis. After confirming a lack of vital signs, attention should be turned to more salvageable patients. Large groups can be managed presumptively based upon levels from individuals most affected. The administration of high-flow oxygen via face mask is top-priority to compete with carbon monoxide for binding sites on hemoglobin and myoglobin. Oxygen toxicity does not occur for hours and is not a reason to withhold therapy.

The most important aspect of the assessment is a detailed mental status and neurological assessment which should include cerebellar and gait testing if possible. Standardized mental status exams have proved more sensitive than gestalt. Serial exams are useful to determine the need for therapy beyond normobaric oxygen.

House fire victims may experience traumatic injury, thermal and inhalational burns, smoke inhalation, carbon monoxide and other toxic exposures such as cyanide. Patients that do not respond to resuscitation efforts may be considered candidates for cyanide treatment particularly in the setting of seizures, coma or lactic acidosis. Measurements of serum or blood cyanide are currently unavailable in a timely fashion. Cyanokit® is the preferred antidote since it avoids induction of methemoglobinemia which can compound hypoxia in CO poisoned patients.

An initial ECG should be performed. While non-specific diffuse ST-T wave changes can occur from carbon monoxide, ischemic changes characteristic of a specific coronary vessel occlusion particularly in someone with cardiac risk factors should prompt emergent cardiology evaluation rather than initial hyperbaric oxygen (HBO) treatment.

CT scanning of the brain is indicated in patients with markedly altered mental status and may reveal ischemia of the basal ganglia, a watershed area vulnerable to ischemia (not specific to CO poisoning).

The cause of greatest confusion in the treatment of CO-poisoned patients is the needs assessment for HBO therapy or transfer to a hyperbaric facility. The decision should not be based upon current or ‘back-calculated” levels but instead upon the likelihood that a patient will likely experience persistent (PNS) or future delayed neuropsychological sequelae (DNS). The HBO chamber is simply impractical for decontamination of blood or tissues beyond what can be achieved by prompt normobaric oxygen. 100% oxygen when administered at 60 feet sea water (fsw) or 2.8 atmospheres absolute (ATA) pressure produces serum oxygen partial pressures above 2000 mmHg. This amount of oxygen is thought to suppress or prevent damaging lipid peroxidation in the brain, that underly the adverse neuropsychological sequelae. While the benefit data is not robust, some randomized controlled trials suggest hastened recovery in those select patients with PNS or DNS, but not hypoxic brain injury.
Consultation with your Toxicologist and Hyperbaricist is recommended if considering HBO. Poison Centers maintain lists of existing facilities that have capacity to accept patients.

Assessment and Management continued on page 6

Assessment and Management continued from page 5

Before HBO therapy, a chest x-ray is necessary particularly with any suspected trauma or bullous lung disease. A chest CT is performed if the x-ray is abnormal or a high index of suspicion for pneumothorax persists. Delays prior to HBO should be avoided since its benefit is greatest if initiated before 6 hours post exposure. A total of three dives within the first 24 hours are standard. Hyperbaric treatment is thought to be safe in pregnancy. While human fetal hemoglobin does not bind CO more avidly than adult HgB, the fetus exists within a relatively hypoxic environment. In the case of multiple victims, a multiplace chamber offers the advantage of simultaneous treatments.

Chronic low level carbon monoxide exposure has controversial adverse health effects and is typically not an indication for any acute therapy beyond removal of source (e.g. cessation of smoking). Subacute exposures beyond 24 hours should be referred as all acute exposures for outpatient follow-up neuropsychological testing to quantify any CO-induced deficits.

Indications for Immediate HBO referral in CO Poisoning

- Lack of life-threatening traumatic injury or untreated pneumothorax.
- Known or suspected CO poisoning with:
  a. scene levels
  b. measured serum COHb
  c. lab results of similarly exposed victim

And at least one of the following:

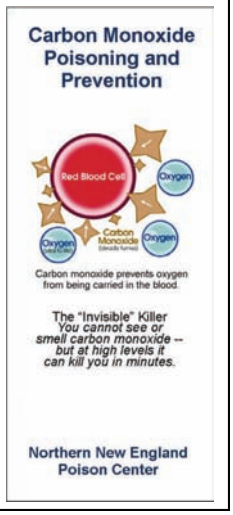
1. Coma, seizure or syncope
2. Despite 4 hours of oxygen therapy:
   a. abnormal mental status testing or neurological complaint (including headache)
   b. cardiopulmonary symptoms with non-diagnostic ECGs and few cardiac risk factors
3. Signs and symptoms of fetal distress

Help the NNEPC Promote Carbon Monoxide Poisoning Prevention!

This October the Northern New England Poison Center is launching a carbon monoxide poisoning prevention educational campaign. We will be working with schools, the media and health care professionals to educate the public on this important issue.

How can I help?

- Visit www.nnepc.org to order educational materials (carbon monoxide informational brochure, hotline stickers, magnets, etc.) to provide to your patients.
- Talk to your patient to make sure their CO alarm is placed properly and in good working order. If they do not have one, encourage them to purchase one.
- Discuss with your patients common sources of CO poisoning, and symptoms to watch out for.



Order the informational brochure "Carbon Monoxide Poisoning and Prevention" from www.nnepc.org.

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If you would like more information about Carbon Monoxide consider viewing the Centers for Disease Control and Prevention Public Health Training Network Webcast – Carbon Monoxide Poisoning Prevention Clinical Education at www2.cdc.gov/phtn/COPoisonPrev/default.asp

Questions

1. T or F Every home should have at least 2 CO detectors/alarms with one near the furnace.
2. T or F Fetal hemoglobin may cause a falsely elevated COHb level in a toddler.
3. T or F 100% oxygen should be provided to CO-poisoned patients until they have emphysema.
4. T or F First responders should wear self-contained breathing apparatus (SCBA) when entering a potentially CO contaminated dwelling.
5. T or F Signs and symptoms of CO poisoning include headache, fever, dizziness and diarrhea.
6. T or F Pulse oximetry can be normal in CO poisoning.
7. T or F CO alarms will go off if toxic blood levels are expected.
8. T or F Subtle cognitive deficits may not be detected by ordinary patient interview.
9. T or F Hyperbaric therapy is used to hasten or further the removal of CO from tissue even when blood CO levels are back to normal.
10. T or F Untreated pneumothorax and pregnancy are contraindications for HBO.

Answers: 1-F, 2-F, 3-F, 4-T, 5-F, 6-T, 7-T, 8-T, 8-F, 10-F

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