A Silent Killer

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Carbon monoxide (CO) is a compound composed of one carbon atom covalently bonded to an oxygen atom (Carbon monoxide, 2018). It is a naturally occurring gas that can be considered one of the oldest toxicological substances and one of the most common causes for both accidental and planned poisonings worldwide (Sykes & Walker, 2016, p. 440). In the United States it is considered the leading poison-related cause of death (Williams & Estrada, 2017, para. 3). Carbon monoxide has been a threat for centuries and little improvements have been made to accelerate the diagnostic process and no new therapies have been approved; however, there are always opportunities for increased awareness and education.

The official journal of the American Nurses Association described an incident in a hotel in North Carolina where a mother and her 11-year-old son were poisoned. Their hotel room was above the indoor pool heater and was improperly ventilated (Williams & Estrada, 2017, para. 1). The next day hotel employees found the mother unconscious and her son dead. Carbon monoxide is a silent killer because it goes undiagnosed since it is colorless, odorless, and a non-irritant gas that mixes with room air (Sykes & Walker, 2016, p. 441). There are approximately 50,000 incidents of carbon monoxide poisoning in a year in the United States (Rose et al., 2017, p. 596). Studies showed there were 1,319 deaths related to carbon monoxide poisoning in 2014 (Rose et al., 2017, p. 596). Since it goes undetected many individuals dismiss the idea that they can be consuming a toxic gas. The safe adult dose of carbon monoxide can be lethal for a child as demonstrated in the journal article.

When carbon monoxide is inhaled a plethora of outcomes can occur ranging from a slight headache and dizziness all the way to coma (Dubey & Chouksey, 2017, p. 672). However, many individuals misdiagnose carbon monoxide poisoning because mild symptoms can be flu-like,
including dizziness, disorientation, weakness, nausea, and vomiting in the early stages of toxicity. (Palmer & Rueden, 2015, p. 480). The differentiating factor is when symptoms become persistent (Ilano & Raffin, 1990, p. 165). This is the reason that improvements have not occurred in diagnosing CO. Symptoms are disguised and take on the appearance of other conditions that cause the diagnosis of CO poisoning to be overlooked.

Carbon monoxide is extremely deadly because of the chemical composition of the molecule. Palmer and Rueden (2015) explained that when inhaled CO diffuses across the alveolar membrane with ease into the blood and the oxygen atom of carbon monoxide binds to hemoglobin forming a stable complex compound called carboxyhemoglobin (COHb) (p. 479). The oxygen atom replaces the space that the free oxygen would normally contain causing COHb to travel through the body instead of a hemoglobin molecule enriched with oxygen. The COHb in the blood causes less oxygen to be carried to tissues making those specific tissues hypoxic (Ilano & Raffin, 1990, p. 166). Individuals are inhaling this toxic gas and believe they are getting lightheaded for other reasons. There have been occasions that patients become exposed to carbon monoxide at work and only seek treatment because coworkers are also experiencing the same symptoms (Sykes & Walker, 2016, p. 442).

The reason carbon monoxide is so poisonous is because it has a 250 greater affinity fold with hemoglobin than oxygen has with hemoglobin (Rose et al., 2017, p. 596). This means that hemoglobin binds exponentially faster to carbon monoxide than oxygen does, depleting oxygen supply in the body. Carbon monoxide binds to any heme-proteins like myoglobin in the heart and skeletal muscles, not just hemoglobin in the blood (Rose et al., 2017, p. 597). Furthermore, CO affects mitochondria by inhibiting the process of respiration causing decreased levels of ATP in the brain and heart (Yan, 2016, p. 1215). Additionally, CO exposure also causes inflammation
through multiple pathways that results in neurologic injury and further cardiac injury (Weaver, 2009, p. 1217). Usually the heart and central nervous system are the susceptible target organs because they require the most oxygen (Ilano & Raffin, 1990, p. 165). This causes a great strain on these major organs and if prolonged depletion of oxygen occurs, arrhythmias and cardiac arrest may happen (Ilano & Raffin, 1990, p. 165). This process occurs rapidly and why it is imperative to diagnose toxicity as promptly as possible.

The World Health Organization (WHO) considers nine parts per million (ppm) for eight hours and 26 ppm over one hour as toxic levels (Ghosh, Narjinary, Sen, Bandyopadhyay, & Roy, 2014, p. 490). Acute exposure of carbon monoxide poisoning is considered within a day and anything above 24 hours is measured as chronic (Sykes & Walker, 2016, 441). Severe symptoms of carbon monoxide exposure can be unconsciousness or hypertension related to renal failure due to the destruction of red blood cells (Palmer & Rueden, 2015, p. 480). When carbon monoxide toxicity occurs the body tries to compensate and raise the partial pressure of oxygen in the arterial blood in response to the reduction in oxygen delivery to the tissue, but a positive feedback loop occurs and increasing respiration leads to greater CO intake complicating the hypoxia already present. (Ilano & Raffin, 1990, p. 166). Therefore, the body tries to regulate the oxygen levels by breathing in more air but in the end it causes more damage since more carbon monoxide is entering the body.

Diagnosis and treatment are essential components for the recovery of the patient. If the proper interventions are implemented as the initial treatment, most, if not all of the sequelae can be prevented (Ilano & Raffin, 1990, p. 168). Wolf (2008) explains that standard treatment for CO poisoning includes the removal from the exposure site, administration of supplemental oxygen, and general supportive care for disease related symptoms (as cited in Buckley, Juurlink, Isbister,
Bennett, & Lavonas, 2011, p. 5). Oxygen is the main form of treatment to improve hypoxia. Applying normobaric oxygen, which is high-flow oxygen through a non-rebreather facemask or 100 percent oxygen, are the initial intervention that emergency medical personnel can provide to a poisoned patient (Weaver, 2009, p. 1219). Then if clinically necessary measuring the arterial blood gases by co-oximetry provides information about the adequacy of gas exchange since a standard oximetry does not suffice, checking for metabolic acidosis and COHb should also be performed in poisoned patients (Weaver, 2009, p. 1219). The goal of treatment is to recompense the lack of oxygen available in the body, reduce the COHb blood levels to a baseline level and remove the CO from the body to relieve the hypoxic systems. It is imperative to remove the source of exposure, if not then all medical assistance is worthless (Ilano & Raffin, 1990, p. 165).

Another form of oxygen therapy can be used is called hyperbaric oxygen therapy HBO, which is typically reserved for severe poisoning cases because of the lack of supply and access. Hyperbaric therapy is 100 percent oxygen at pressures greater than three atmosphere absolute (ATA), which could increase risk for oxygen-induced seizures ((Palmer & Rueden, 2015, p. 480). Several non-randomized trials and case series suggested the treatment of HBO would prevent the development of two syndromes; persistent neurologic sequelae and delayed neurologic sequelae that are commonly recognized after acute CO poisoning (Buckley et al., 2011, p.5). The main symptoms of these syndromes are subtle personality changes, mood disorders and memory loss and range to sever impairments. Despite HBO not being clinically proven yet and cannot be routinely encouraged there are several articles that recommend hyperbaric oxygen therapy especially for those with more severe poisoning. Other researchers suspect that brain damage from carbon monoxide toxicity is reversible. This study used magnetic resonance imaging (MRI) of a 55 year-old female at presentation of symptoms and then another
MRI scan at a follow visit two months later with no re-occurrences (Dubey & Chouksey, 2017, p. 672). The patient left the stove on that uses wood and coal on all night while she slept. At presentation there were presentations of hyperintensities but then they were not present at the two-month follow up (Dubey & Chouksey, 2017, p. 672).

Carbon monoxide is a continuous problem but what is so shocking is that it can be completely prevented if the right measures are taken place. Advocacy for patients and the community should be a priority when it comes to carbon monoxide. Exponential intended and accidental cases and deaths continue to emerge. This is a public health problem worldwide. There have been special advocacy campaigns to encourage the awareness of CO like Invisible killer that promotes the reduction of air pollutants and the mandatory checks of catalytic converters in vehicle to reduce the CO pollution rates. However, only by educating prior to exposures of the causes, changing the continuous habit of neglecting to check appliances and get them serviced, installing CO detectors, diagnosing patients quicker, advocating for patients exposed of treatments available, and continuing to research the best diagnostic equipment and treatments will carbon monoxide poisonings reduce.

As stated by Weaver, COHb levels of three percent or more can adversely affect high-risk groups such as the elderly, pregnant women, fetuses, infants, and patients with cardiovascular or respiratory diseases which is why the governmental air-quality limits carbon monoxide levels below three percent for nonsmokers (2009, p. 1220). There is a different acceptable level of ten percent COHb for smokers because of the toxins released by the cigarette smoke (Williams & Estrada, 2017, para. 9). It is essential that people help those that are more immunocompromised to these toxics. Fetuses can develop skeletal abnormalities or neurological damage causing impairments of memory and cognitive functioning depending on which
trimester the fetus is exposed to the carbon monoxide (Palmer & Rueden, 2015, p. 479).

Furthermore, since a fetus has one-fifth partial pressure of the mother any presentation of carbon monoxide will be more hazardous to the fetus (Palmer & Rueden, 2015, p. 479). Moreover, pregnant mothers are at risk of being misdiagnosed because symptoms can be presumed to be related to the pregnancy or be shoved off as a mental health problem (Palmer & Rueden, 2015, p. 482). It is imperative that nurses in psychiatric wards be alert and assess patients that can be misdiagnosed with a mental health problem when carbon monoxide is actually the cause of symptoms because the symptoms can also be disguised as a mental health condition (Bhagwat & Bruxner, 2017, p. 595).

Primary prevention is educating the public about the situation and more importantly the foundation to prevent toxicity. Internal combustion engines that cause incomplete combustion are the main environmental source of carbon monoxide (Rose et al., 2017, p. 596). The main causes of accidental deaths are due to fires and smoke inhalation. 10,200 visitations to the emergency department are related to accidental carbon monoxide poisoning from consumer products (National Center for Healthy Housing, 2017, para. 5). The Center for Disease Control and Prevention has a list under the Carbon Monoxide Poisoning Prevention of “dos” and “don’ts” that can help prevent the exposure of carbon monoxide (CDC Features, 2018, para. 4). The main idea of all the factors listed is to make sure that the carbon monoxide is well ventilated and being expelled out and never contained in an enclosed space.

Carbon monoxide detectors are another form of prevention. Installing a battery-operated detector in your home is the initial step but it is crucial to have continuous check ups of the system, therefore, replacing the batteries when you change the time on your clocks each spring and fall is a great tip (CDC Features, 2018, para. 1). It is also essential that people get their
heating system, water heater and any other gas, oil, or coal burning appliances serviced by a qualified technician every year and if the detector ever sounds it is important to leave your home immediate and call 911 (CDC Features, 2018, para, 4). There needs to be more awareness to the public of these prevention methods.

In New York City on November 1, 2004, Local Law 7 was passed which obligated residences, nursing homes, hotels, hospitals, schools, and library buildings to have carbon monoxide alarms. The only builds exempt from the law those are without and not adjacent to any fossil fuel burning heating sources or had an attached garage (Wheeler-Martin et al., 2015, p. 1623). Five years after the passage of NYC’s CO alarm law, the Community Health Survey estimated that 82.7 percent of their residents had a CO alarm in their home, which collectively demonstrated that the law did have a promising impact on the community (Wheeler-Martin et al., 2015, p. 1626). The study stated that further investigation needed to be conducted to identify the specifics of all the hospitalizations and the percentage of the population that did not install a device (Wheeler-Martin et al., 2015, p. 1628).

A study in Wales demonstrated some of the ways carbon monoxide teaching could be a primary and secondary form of prevention. In a pilot trial 70 participants that lived in very low-income homes or rented were educated about the symptoms and prevention methods of CO and were given an alarm detector with instructions; 54 of those participants partook in a follow-up meeting and demonstrated improved knowledge (Jones et al., 2016, p. 409). All the feedback was positive because individuals believed they learned something important and effective. Despite many individuals not installing the devices because they believed that was the landlord’s responsibility, or they wanted to move to a better location before installing the device, or thought the instructions were too complicated; many individuals did keep the yellow CO warning and
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information sheet given to them and had memorized it (Jones et al., 2016, p. 411). There is an importance in education and arming people with the correct equipment. In a more broad spectrum several local authorities preformed home visits were CO levels were checked in the participants’ homes and if the property contained more than 10, which was two home, were evacuated and the CO level was decreased to zero before residents returned (Jones et al., p. 411). This information demonstrates that follow-ups have to be conducted to assure that devices are being installed but it also acknowledged that these participants did increase their knowledge about CO and had a positive outlook on it. The New York City law and the trials composed in Wales are examples of interventions the community and government can implement to reduce carbon monoxide poisoning.

Family members also have a responsibility to keep their homes safe. As described earlier the proper maintenance of carbon monoxide detectors and appliances are essential for home safety. Placement of detectors where they can wake the individual up like outside bedrooms is important to keep in mind when installing the device (Carbon Monoxide Poisoning, 2017, para. 4). Furthermore, family members should never heat up vehicles in garages; they should turn off any potential source of the carbon monoxide, and notify the landlord and services need (National Center for Healthy Housing, 2017, para. 11). When a family member is experiencing symptoms everyone should evacuate the location and seek medical attention (National Center for Healthy Housing, 2017, para. 12). The promptness of family members will help aid medical personnel to provide assistance more rapidly and already know the cause. The problems that are occurring is that there are met situations when the individual is alone or the whole family is affected before help be called for.
Moreover, medical personnel also have contributing factors when addressing carbon monoxide poisoning. When the patient is admitted into the hospital the nurse is the initial source to prevent prolonged treatment and should be familiar with the common sign and symptoms to suspect poisoning in individuals (Williams, & Estrada, 2017, para. 11). As described by Palmer and Rueden (2015), “nurses have the important role in both identifying CO exposure and ensuring that patients receive the proper care” but this can only be done if a proper history is conducted (p. 480). If thorough environmental assessment and questioning are not performed accurately it could cause increase stress levels for the patient and family, cause financial burden from hospital bills and missed work days, and cause long-term neurologic damage that evidently can cause impaired memory and cognitive functioning (Palmer & Rueden, 2015, p. 479). When a nurse does suspect toxicity, oxygen should be administered immediately.

After suspicion the nurse can then advocate for their patient by requesting a COHb laboratory test to confirm CO poisoning. This is important because conventional pulse oximetry cannot distinguish between COHb and oxyHb therefore, CO oximetry levels should be confirmed with laboratory testing (Rose et al., 2017, p. 599). Furthermore, nurses can call local hyperbaric resource centers to notify personnel and involve specialists who can collaborate and ensure if the patient is receiving proper care and treatment (Palmer & Rueden, 2015, p. 482). Additionally, it is important to allocate time because there is a significant delay between the diagnoses in the field to the transportation to a hyperbaric therapy center where they will receive HBO2 (Rose et al., 2017, p. 600). The only study to meet all Consolidated Standards of Reporting Trials criteria and measure one-year outcome was the Weaver and colleagues trial. This study did show a significant improvement in long-term neurocognitive dysfunction, and should be weighed most heavily in judging the effectiveness of HBO2 (Rose et al., 2017, p. 600).
Once treated it is critical that patients receive thorough discharge teaching to prevent future CO exposures (Palmer & Rueden, 2015, p. 482).

Beyond public awareness and public safety efforts, which have been effective in prevention, there is an unmet clinical need for better therapies for carbon monoxide poisonings. To this date there is no antidotal therapy for it. However, Wudan Yan (2016) reported about two biomedical scientists, Ling Wang and Qinzi Xu, from the University of Pittsburgh in Pennsylvania, who conducted a study of neuroglobin, a protein typically found in the brain and retina that protects cells from injury by binding oxygen and nitric oxide (p. 1215). A lethal dose of CO was exposed to mice and the neuroglobin was repurposed into a CO scavenger, which saved 87 percent of mice (Yan, 2016, p. 1215). Lindell Weaver, a doctor who treats patients with high-pressure oxygen at Intermountain Healthcare in Salt Lake City, whom is mentioned in other studies, described neuroglobin as a phenomenal agent. “It can rip carbon monoxide right off the hemoglobin” (Yan, 2016, p. 1215). He continued to describe that the long-term effects of carbon monoxide as complex, and how removing carbon monoxide from the body is not sufficient enough, “but this agent could be life-saving if it’s administered immediately” (Yan, 2016, p. 1215). There definitely needs to be additional clinical trials related to the efficiency and dosage elements of neuroglobin before it can reach human trials but this is moving in the right direction.

Carbon monoxide poisoning has been a public health issue for years since symptoms are vague and patient specific. There are still many advances in technology that need to occur to help reduce the chances of long-term neurological damage. Furthermore, government prevention methods have increased public knowledge of the situation but there still needs to be more awareness. Furthermore, it in essential for medical profession to conduct a detailed assessment
including the environmental factors that can possible impact the patient. Overall, the main point of carbon monoxide is that it is preventable and better prevention methods need to be in place.
References


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