Asphyxiants: Simple and Chemical

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Abstract

Asphyxiants are gases that cause tissue hypoxia. They are classified as either simple or chemical on the basis of the mechanism of toxicity. Simple asphyxiants decrease FiO_2 by displacing oxygen in inspired air, results in hypoxemia. Chemical asphyxiants interfere with oxygen transport system and cellular respiration and thereby cause tissue hypoxia. Mild symptoms of asphyxia include headache, dizziness, nausea, and vomiting. More severe symptoms range from dyspnea, altered sensorium, cardiac dysrhythmia, ischemia, syncope, seizure, and even death. Clinical diagnosis of asphyxiant exposure is limited. A consistent history, myriad spectrum of complaints, group victims, and rapid resolution on away from exposure are generally sufficient. Occupational exposures and fires are the most common sources of inhalation injuries. Working in confined spaces are harzardous to workers. Rapid removal, supportive care and preventing hypoxemia are the mainstay of treatment. Emergency planning should be applicable to both accidental and deliberate chemical disasters. *(Ann Disaster Med. 2005;4 Suppl 1:S35-S40)*

Key words: Asphyxiants; Asphyxiation; Toxic Inhalation; Carbon Monoxide; Cyanide; Hydrogen Sulfide

Introduction

Asphyxiants are gases that deprive body tissues of oxygen. They are generally divided into two categories, simple and chemical.[1] Simple asphyxiants merely displace oxygen from ambient air whereas chemical asphyxiants react in the human body to interrupt either the delivery or utilization of oxygen.[2] When the concentration of any gases increase, the fraction of inspired oxygen (FiO2) tends to decrease, rendering to hypoxemia.

Working in confined spaces are hazardous to workers.[3] The death is usually due to hypoxemia, secondary to gases inhalation.[4] Occupational exposures and fires are the most common sources of the numerous agents accountable for accidental inhalation injuries. When obvious historical evidence or a heightened suspicion for an acute inhalation exposure does not exist, misdiagnosis and maltreatment are likely to occur.

Clinical diagnosis of simple asphyxiant exposure is limited. A consistent history, myriad spectrum of complaints, group of victims, and rapid resolution on away from exposure are generally sufficient. Identification of particular

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gases is not necessary except for government health politics.

Supportive care and preventing hypoxemia is central to the treatment of all pulmonary and systemic inhalation injuries.[5] Patients at risk for hypoxia should be observed for the delayed development or progression of post hypoxic neurological sequelae.

Classification

Simple asphyxiants, such as carbon dioxide (CO_2), Nitrogen (N_2), and Propane (C_3H_8), when present in high concentrations in air, especially within a confined space, act by limiting the utilization of the oxygen, without producing significant toxic effects on the body per se.

Clinical reports on unintentional mass exposure to extreme concentrations of carbon dioxide occurs in Israel, caused by a leakage of container of liquid carbon dioxide in an enclosed working environment. Twenty-five casualties developed symptoms included dyspnea, cough, dizziness, chest pain, and headache. It resulted in significant but transient cardiopulmonary morbidity with no mortality when victims were promptly evacuated and given supportive therapy.[6]

Most diving injuries are related not only to barotraumas, decompression illness, pulmonary edema, but also nitrogen narcosis at elevated levels.[7]

Another categories of asphyxiants, i.e., chemical such as carbon monoxide (CO), cyanide (CN^-), and hydrogen sulfide (H_2S), bind to and inhibit the ultimate step in electron transport chain system of the mitochondria, the Fe^{3+} containing cytochrome a-a^3 in complex IV, therefore, rendering tissue hypoxia and the development of lactic acidosis.

Many cases of CO poisoning, even recover well without any complication with hyperbaric or high oxygen therapy, revisit hospital with delayed neuropsychiatry sequelae, such as cognitive and personality changes, incontinence, dementia, and psychosis.[8]

Clinical Features

Decrease FiO_2 from ambient, (i.e., 21%) to 15% brings acute effects of hypoxia within minutes after exposure to simple asphyxiant. It results in autonomic stimulation (e.g., tachycardia, tachypnea, and dyspnea) and cerebral hypoxia (e.g., ataxia, dizziness, incoordination, and confusion). Life probably cannot be sustained at a FiO_2 level below 6%.[9]

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless, nonirritating gas that is widely used as a fire extinguisher, in ice-making factories and occupational or recreational (diving) settings. The potential severity of toxicity from carbon dioxide was tragically exemplified by the disaster in Cameroon in 1986, when many people were killed by the expulsion of carbon dioxide from a volcano.[11]

CO_2 closely resembles simple asphyxiants from a toxicological standpoint. CO_2 in high concentration, however, has direct toxic effects, mainly those of sympathetic stimulation, including increased heart rates, cardiac output, mean pulmonary artery pressure, and pulmonary vascular resistance, and therefore impose excess load on the myocardium. The most important action in CO_2 intoxication is to remove the victims from the exposed environment and to provide cardiorespiratory support until spontaneous recov-

ery occurs.[6]

Nitrogen

Nitrogen gas (N_2) is a colorless, odorless, tasteless, and constitutes about 80% of air in atmosphere. The incident rate of nitrogen narcosis (12%) is the most frequent, followed by barotraumas of the ear (11%) and paranasal sinus (5.6%) during scuba diving. [11] The major toxic effect is simple asphyxiation. N_2 is thought to act by interacting directly with neuronal ion-channel receptors i.e., [gamma] - aminobutyric acid (GABA) receptor antagonists.[12]

Propane

Propane (C_3H_8), which is both colorless and odorless in its gaseous state, has highly flammable and explosive characteristics. It displaces oxygen, consequently causing hypoxia and eventually anoxia. The depletion of oxygen in the air, and the build up of propane and carbon dioxide, lead to unconsciousness and eventual death. Death results not from the toxic nature of the gas but simply from the displacement of atmospheric oxygen.[13]

Inhalation of gaseous propane can cause dizziness, nausea, vomiting, confusion, hallucinations, and a feeling of euphoria. At high concentrations, it has a narcotic effect and can bring about cardiac arrest resulting from suppression of central nervous system activity.[14]

Carbon monoxide

Carbon monoxide (CO) is, after carbon dioxide, the most abundant atmospheric pollutant. It originates partly from natural sources such as forest fires and volcanic eruptions, but mostly from human activity, in particular from the internal combustion engine and industrial discharges.

The key to the pathogenicity of CO is its propensity to attach itself to the ferrous (Fe^{3+}) in the heme prosthetic group of hemoproteins, which includes hemoglobin, myoglobin, and some intracellular enzymes (cytochromes, P-450). Contributing to tissue hypoxia is the failure of carboxyhemoglobin to dissociate in the tissues.[15]

Mild CO poisoning occurs frequently, leading to headache, nausea, vomiting, dizziness, myalgia or confusion. However, in severe CO intoxication, patients suffered from neuropsychiatry abnormality or cardiovascular instability (e.g. alter sensorium, seizure, coma, syncope, ischemia, infarction, or dysrthymia). It would depress myocardium contractility and lead to acute rhabdomyosis.

Hydrogen Cyanide

Cyanides (CN^-) are utilized in mining operations, photographic materials, the production of plastics, pigments, and dyes, and often used as fumigant pesticides. During fires, victims can also inhale significant carbon monoxide and cyanide gases, which may cause synergistic toxicity in humans.

CN^- is described as a cellular toxin because it inhibits aerobic metabolism. It reversibly binds to cytochrome oxidase and inhibits the last step of mitochondrial oxidative phosphorylation. This inhibition halts carbohydrate metabolism from the citric acid cycle, and intracellular concentrations of adenosine triphosphate are rapidly depleted. [16]

With the inhalation of high concentration hydrogen cyanide (300 mg/m^3), the victim's skin is a flushed reddish pink, and tachypnea, tachycardia, and nonspecific central nervous

symptoms appear. Stupor, coma, and seizure immediately precede respiratory arrest and cardiovascular collapse. Death shortly occurs.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a colorless, flammable gas. H_2S has a pungent odor reminiscent of rotten eggs. There is the potential for widespread occupational exposure to H_2S, including in the oil and water treatment industries. H_2S selectively binds to the enzymes involved in cellular respiration thereby causing a shift towards anaerobic respiration.

At higher concentrations, death is caused by depression of respiratory center in the brain; at lower concentrations, death is caused by pulmonary edema and congestion. Survivors wtih periods of unconsciousness may suffer permanent neurological sequelae such as memory loss. High exposures to near lethal concentrations in animals have shown destruction to nasal epithelium. During vigorous exercise, low level exposures (5–10 ppm) cause a shift to anaerobic respiration, leading to increased lactic acid formation. Eye irritation, so-called "gas eye, only occurs at high exposure concentrations.[17]

Diagnostic Strategies

Clinical diagnosis of simple asphyxiant exposure is limited. A consistent history, myriad spectrum of complaints, group of victims, and rapid resolution on away from exposure alert the suspicion of asphyxic agent. The diagnosis always required scene investigation by a trained and outfitted team.

Since the presenting complaints are nonspecific and protean, alertness should be kept for those who visit ED with unusual presentations. The circumstances and locations of the exposure, presence of combustion or odors, and number and condition of victims assist in diagnosis.

In case of chemical asphyxiant, there are certain kinds of laboratory test (CO-oximeter, pulse oxymetry, arterial blood gas, MetHb level, lactate) can be used to aid in confirm diagnosis.

Treatment

Rapid removal, away from the asphyxiant, and supportive treatment with oxygen supplement are the mainstay of treatment. Neurological injury and cardiorespiratory instablability should be managed with standard resuscitation protocols.

Patients with asymptomatic or mild poisoning who recover after removal from the exposure can be observed briefly and referred to outpatient for follow up of possible delayed neurological sequalae. Patients who are at risk of hypoxia, such as cardiopulmonary comorbidity, advanced age, or exacerbating medical conditions, should admitted for further management and observation.

In cases of carbon monoxide, cyanide or hydrogen sulfide, administer 100% oxygen. Oxygen reverses hypoxemia and accelerates the elimination of asphyxiants. [19] HBO has been shown to be the standard treatment for severe CO poisoning. It reverses hypoxia, competes with CO for hemoglobin binding, and promotes carboxyhemoglobin dissociation. It shortens carboxyhemoglobin half-life from 4–6 h to <30 min.[20]

CN^- poisoning is treated with amyl nitrites, sodium nitrite and thiosulfate, all of which are in the Antidote Kit. Nitrite induces the formation of methemoglobin, which is bound by CN^-,

yielding cyanomethemoglobin. Thiosulfate acts synergistically to accelerate the detoxification of CN^- to thiocyanate.[21, 22]

For CN^- poisoning due to smoke inhalation, most authorities recommend the use of thiosulfate, oxygen, and supportive measures. Nitrite-induced methemoglobinemia aggravates the decrease in oxygen-carrying capacity that is due to carboxyhemoglobinemia.[23]

The treatment of victims of H_2S poisoning is similar to that used for hydrogen cyanide poisoning. It involves parenteral administration of a methemoglobin inducing agent such as sodium nitrite. Methemoglobin binds with HS^- ions to form sulfamethemoglobin, and thus restores the activity of the sulfide inhibited cytochrome oxidase enzyme.[17]

General Precautions

In all cases of exposure to chemical asphyxiants, a successful outcome emphases on the extrication of casualties, immediate provision of basic life resuscitation, and follow-up with good supportive care. Community alertness for nonpredictable toxic chemical releases requires well-organized emergency-medical-response systems, as well as emergency physicians and hospitals trained for readiness. Emergency planning should be applicable to both accidental and deliberate chemical disasters.[19]

Conclusion

Asphyxiants are gases that deprive body tissues of oxygen. The fraction of inspired oxygen (FiO2) tends to decrease with the present of high concentration of certain asphyxiant, especially in a confined space, accountable for accidental inhalation injuries. When obvious historical evidence or a heightened suspicion for an acute inhalation exposure does not exist, misdiagnosis and maltreatment are likely to occur. Supportive care and preventing hypoxemia is central to the treatment of inhalation injuries. Antidotes and hyperbaric therapy aid in treatment of specific chemical asphyxiant. Patients at risk for hypoxia should be observed for the delayed development or progression of post hypoxic neurological sequelae. Alertness should be paid on group of victims who visit ED with unusual presentations of illnesses.

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