Asphyxiants

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KEYWORDS

• Asphyxiants • Cyanide • Hydrogen sulfide • Carbon monoxide • Hydrazoic acid • Azide • Methemoglobinemia • Antidote

KEY POINTS

- Asphyxiants deprive the body of needed oxygen via displacement (simple asphyxiants) or by interfering with transport or use of oxygen within tissues and organs (systemic asphyxiants).
- Asphyxiants may be gases, liquids, or solids and may enter the body by multiple routes.
- Bedside clinical diagnosis is essential, because confirmatory tests are often delayed or unavailable.
- The asphyxiant toxidrome, supported by a careful history and search for distinguishing clinical features, helps to narrow the differential diagnosis.
- Aggressive supportive care is often lifesaving in these poisonings.
- Early use of appropriate antidotal therapy is effective against severe carbon monoxide, cyanide, and opioid poisonings and toxicant-induced methemoglobinemia.

INTRODUCTION

Asphyxia is defined as impaired or absent exchange of oxygen and carbon dioxide on a ventilatory basis; combined hypercapnia and hypoxia or anoxia. Stedman's further defines an asphyxiant as "anything, especially a gas that produces asphyxia."[1] Although people tend to think of highly, toxic gases when discussing asphyxiation, it is particularly important for the emergency physician to keep in mind that asphyxiants may be gases, liquids, or solids, and can potentially enter the body not only by inhalation but also by skin absorption, ingestion, or injection. The speed of onset of symptoms is determined not only by the substance's inherent toxicity and physical characteristics, such as water solubility, but by its propensity for metabolism to toxic

The opinions and comments of the authors do not reflect official policy, position, or product endorsement of the Department of the Air Force, Department of Defense, or US Government. Disclosures: None.

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Emerg Med Clin N Am 33 (2015) 89–115

http://dx.doi.org/10.1016/j.emc.2014.09.014 **emed.theclinics.com**

0733-8627/15/$ – see front matter

byproducts. Thus, although inhalation of hydrogen sulfide gas in high concentrations may result in immediate knockdown and apnea, symptoms of asphyxia after ingestion of sodium azide may lag by an hour or so,[2] and symptoms of cyanide poisoning after ingestion of acetonitrile by half a day or more.[3] Failure to recognize the role of active metabolism of cyanogens to cyanide or of dichloromethane to carbon monoxide (CO) may contribute to avoidable deaths.

Mechanisms of Asphyxia

Asphyxia may occur through several mechanisms. First, oxygen in inspired air may be replaced by other gases, depriving the body of sufficient atmospheric oxygen. Such gases need not have intrinsic toxicity. Even inhalation of inert gases, such as helium or argon, may lead to death.[4] The condition of (near) death resulting from inadequate atmospheric oxygen is referred to as simple asphyxia. Another form of simple asphyxia results from inability of oxygen to reach the pulmonary capillaries for exchange with carbon dioxide. This condition may occur after exposure to irritant or corrosive gases resulting in upper airway obstruction, bronchospasm, pulmonary edema, or hemorrhage. See the article by Tovar and Leikin in this issue.

In contrast, systemic asphyxia results from exposure to a compound that directly impairs either transport of oxygen via hemoglobin (CO, methemoglobin inducers) or interferes with the efficient use of oxygen at the tissue level via inhibition of oxidative phosphorylation (azides, CO, cyanides, sulfides; **Fig. 1**). There have been significant advances in recent years in understanding of the inhibition of cytochrome-c oxidase by CO, hydrogen cyanide, hydrogen sulfide, and nitric oxide (NO). Physiologic roles for these compounds, as well as their toxicity, have been described by Cooper and Brown.[5]

CIRCUMSTANCES

Unintentional

The circumstances leading to asphyxia are manifold. Most cases are unintentional. CO is the leading cause of unintentional poisoning deaths in the United States.[6] Household exposures to CO may derive from defective furnaces, improper indoor use of generators, and charcoal cooking devices, among others. On average, there are 430 non–fire-related CO deaths per year in the United States.[7] The number of injuries attributable to CO is far greater. Some 68,316 CO exposures were reported to poison centers during 2000 to 2009. Of these, 36,691 people required treatment in a health care facility, with 9625 having moderate to major effects.[6] Industry is responsible for a concerning number of unintentional deaths from asphyxiation. On average, 22 workers die on the job each year from CO poisoning in the United States.[8] Many additional workers seek care in emergency departments after CO exposures.

Another source of industrial asphyxiation is improper confined space entry. The Occupational Safety and Health Administration describe confined spaces as areas not necessarily designed for continuous occupancy, with limited or restricted means for entry or exit. Confined spaces include, but are not limited to, tanks, vessels, silos, storage bins, hoppers, vaults, pits, manholes, tunnels, equipment housings, ductwork, and pipelines.[9] Such areas by their nature are conducive to depletion of atmospheric oxygen (with occupancy) and concentration of gases that are lighter (silo) or heavier (sewer) than air. Notorious industrial multiple casualty incidents involving asphyxiant gases have been reported. A synopsis of federal and state confined space incident investigations can be found at the Web site of the National Chemical Safety Program and in a review by Dorevitch and colleagues.[10,11]