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An Apple a Day Does not Always Keep the Doctor Away…

ABSTRACT: The authors describe a case of suicide in the workplace. A 45-year-old man employed by a fruit and vegetable packing company was found dead in a room containing a modified atmosphere for the packaging of fruits and vegetables. The rescue team measured the carbon monoxide (CO) concentration of the ambient air with a digital CO tester and found a level higher than 600 particles per million. Analysis of an arterial blood sample taken with an airtight syringe revealed the absence of CO but high levels of carbon dioxide (CO_2). Autopsy revealed no significant injury and police investigators found a handwritten note of intent, describing a recent personal crisis. The authors concluded that the cause of death was suicide by asphyxiation secondary to CO_2 intoxication and notably oxygen (O_2) depletion. This manner of suicide is rare and most cases previously described in the literature were accidental intoxications. To the best of our knowledge, this is the first case of suicide by CO_2 intoxication and O_2 depletion in a room with a modified atmosphere.

KEYWORDS: forensic science, carbon dioxide, intoxication, suicide, occupation

Typical room air consists of 20.9% oxygen (O_2), 79% nitrogen and 0.1% carbon dioxide (CO_2), water vapor, and other inert gases (1). The alveolar concentration of CO_2 in the human lung is 5%. CO_2 produced by cellular respiration is removed by pulmonary ventilation. If the concentration of inspired CO_2 increases, it alters the normal diffusion gradients of alveolar blood. Increased alveolar CO_2 results in hypercarbia and systemic acidosis. Loss of consciousness and death can occur if the concentration of atmospheric CO_2 reaches 10%. Under normal ambient conditions, CO_2 is a colorless, odorless, nonexplosive gas, heavier than O_2 (1,2). At high concentrations, it produces an acid taste in the mouth as it dissolves in mucosal fluid to form carbonic acid (2). Displacement or deprivation of environmental O_2 is a common method of suicide and has also been reported in rare work-related industrial accidents (1). Occupational deaths have occurred in ship holds, the brewing industry, silos, tunnels, sewer shafts, and poultry plants that use dry ice. We describe a case of occupational suicide by CO_2 intoxication in a company packing fruits and vegetables in a modified atmosphere.

Case Report

Case History

A 45-year-old male employee of a fruit and vegetable packing company was found dead on the floor in his workplace (Fig. 1). The death occurred in a confined room used for special packaging of vegetables, apples, and other fruits. The atmosphere of this room was modified in order to increase the shelf-life of packaged apples (Fig. 2). External examination showed no sign of a struggle and the victim had no history of psychiatric disorders or medical illnesses. The rescue team and general practitioner who were first on the scene believed the cause of death could be carbon monoxide (CO) intoxication. They analyzed the ambient air in the room and the digital CO tester indicated a high level of CO, more than 600 particles per million, and an O_2 concentration of 3%. At the deceased's home, police investigators found a handwritten note of intent describing a recent personal crisis, stating that his wife had left home and wished to divorce. Peripheral and cardiac blood samples and urine samples were taken for toxicological studies. Peripheral arterial blood was sampled with an airtight syringe in order to measure CO level. As the man had died in the workplace, a medicolegal autopsy was ordered.

Autopsy Findings

An autopsy was performed by a board-certified forensic pathologist. All three body cavities (cranium, thorax, and abdomen) were examined. External examination of the body was significant for an absence of cherry red lividity, which is normally an indicator of CO intoxication. There were no notable injuries or traumatic lesions. All organs were grossly unremarkable.

Toxicological Study

Toxicological tests included blood ethanol levels and screening for common drugs, and illegal substances by high-performance liquid chromatography and gas chromatography and mass spectrometry. Tissue specimens of all organs were collected and histological examination of all major organs was performed.

Analysis of the airtight peripheral arterial blood sample found a carboxyhemoglobin level at 2% and an O_2 level at 34.1%. The cause of death was therefore unclear. Complementary toxicological tests were performed. The partial arterial CO_2 level was 204 mmHg and the O_2 level 38.6 mmHg. The normal range of partial arterial CO_2 for living subjects is 40–60 mmHg and of partial arterial O_2 is 60–95 mmHg.

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FIG. 1—*View of the interior of the shed where numerous boxes containing apples are stored. The entrance to the room where the deceased was found can be seen on the right.*

FIG. 2—*View of the entrance door of the room containing modified atmosphere. A danger warning sign is clearly visible in front of the entrance.*

Death was attributed to asphyxiation caused by CO_2 intoxication and notably O_2 depletion. The manner of death was determined to be suicide. The high CO_2 and low O_2 level within the room and in the blood sample suggested instantaneous loss of consciousness after entry inside the room followed by death. The deceased had worked in the packing company for many years and knew that there was a fatal risk if he entered the room if it was not aired beforehand.

Discussion

Mechanisms of Toxicity

CO_2 dissolved in plasma (PCO_2) is primarily responsible for our respiratory drive (1). The central nervous system closely controls PCO_2 through its regulation of breathing (2). Exogenous CO_2 has been used in combination with O_2 as a respiratory stimulant in neonates. An animal study in dogs has examined the effects of increasing the environmental concentration of CO_2 to 80% while maintaining normal atmospheric O_2 concentration to 20% (3). The blood pressure showed an initial depression, then returned to the original level, then fall again rapidly or maintained an appreciable level for a while until circulation breakdown. In the dogs, allowed to breathe the gas mixture of 80% CO_2 with 20% O_2, the respiratory movement ceased in 1 min, and the terminal respirations were seen with the circulation breakdown after apnea of several minutes. These findings demonstrate that death caused by sufficiently high levels of environmental CO_2 is due to its harmful chemical effects on the body. Displacement of environmental O_2 by CO_2 may also contribute to death, but is not a requisite (2). The cause of death in breathing high concentrations of CO_2 is not hypoxia but the CO_2 poisoning (3). CO_2 intoxication may be acute or subacute.

Subacute toxicity may be caused by the body's failure to eliminate endogenous CO_2, as occurs in hypoalveolar ventilation resulting from chronic obstructive pulmonary disease, opioid poisoning, or other causes of respiratory failure (2,4). Medical interventions, such as permissive hypercapnia, can also cause subacute CO_2 toxicity, which typically manifests itself as gradual somnolence (2).

Persons exposed to high levels of CO_2 in the environment, on the other hand, may experience immediate hypoxia or anoxia in response to the displacement of ambient O_2. The displacement of breathable O_2 by another gas produces asphyxiation through impaired pulmonary gas exchange culminating in hypoxemia. Asphyxiation may be caused by a physical mechanism, such as choking, or by the reduction of the O_2 content in breathable air. A person who has suffocated in a plastic bag, for example, has actually asphyxiated from the selective depletion of O_2 caused by rebreathing into the bag. Fire may deplete ambient O_2 and produce asphyxiation independently of the effects of smoke inhalation or CO poisoning.

In spite of rapid postmortem PCO_2 increase and because of the context of the death, PCO_2 level was measured. The PCO_2 level was so high (204 mmHg) and the PO_2 level so low (38.6 mmHg) that it was possible to conclude that death was due to two associated causes: substantial O_2 depletion and contributory CO_2 intoxication (1).

Clinical Signs of CO_2 Intoxication

(i) Up to 45 mmHg of PCO_2, clinical signs are nonspecific: dyspnea, hyperventilation, dilatation of brain arteries, and arterial hypertension may occur (1).

(ii) At 75 mmHg, mental and physical capacities decline and can lead to delirium.

(iii) At 100 mmHg, convulsions and coma may ensue.

(iv) At 150 mmHg, fatal ventricular fibrillation occurs because of catecholamine release.

Other Sources of CO_2 Exposure

Occupational exposure to CO_2 is widespread. The five major categories of CO_2 exposure are occupational use, sources of fermentation in confined spaces, telluric sources (caves, wells, mines, tunnels, basement flats, sewers), endogenous production of the gas in confined spaces (submarines, diving tanks, scuba diving tanks), and various other origins (mainly fire) (5). A common characteristic of these sources of exposure is the presence of a confined space, that is, where natural exchanges between internal air and external atmosphere are reduced. Air movement may be restricted because of narrowness of the space compared with its length or depth, or because it is closed.

CO_2 is used in carbonation of soft drinks and as a shielding gas for welding. It may also be used for conservation and packaging of foodstuffs, such as fruit juices or wine. One of the new techniques for extending the life of fruits and vegetables is conservation in a modified atmosphere (6). The atmosphere generated within the packaging containing the foodstuffs is different from the ambient air. Generally, the level of CO_2 is increased and the level of O_2 decreased. The aim is to slow down the maturation of the packed fruits or vegetables. Their shelf-life depends on their respiratory intensity and this can be decreased by lowering the temperature or modifying the atmosphere. Low ambient O_2 level decreases the synthesis of ethylene, which is the maturation hormone. This technique is used with mushrooms, cherries, and in particular with apples. The procedure consists of maintaining foodstuffs in a gas mixture under plastic film. Compressed CO_2 gas is widely used as a fire extinguisher because of its ability to safely displace O_2 from the atmosphere surrounding a fire. When the gas is released in a closed space such as an airplane, however, that property may prove lethal (1). Dry ice is often used to generate artificial smoke for stage productions and is widely employed in the biomedical and transportation industries. Storage of dry ice in closed spaces, such as submarines and automobiles, has proved hazardous in the past (2,7).

CO_2 is produced when organic material decomposes or ferments, and asphyxiation from CO_2 exposure has occurred in workers entering grain elevators (cereal storage), the holds of cargo ships, and brewery vats (2). It is more likely to occur when these spaces are not aired or ventilated or when the ventilation system does not function correctly (5). In vats containing alcohol (wine, beer, cider), high concentrations of CO_2 accumulate to form a homogeneous cover. In wine vats, CO_2 may be produced during the fermentation of the grapes and also during wine storage, and vat cleaning. The gas concentration varies widely within a few centimeters (5,8). In a well-ventilated fermenting room, during fermentation the CO_2 concentration is 2.5% when measured 0.5 cm above the top of the vats, and 40% when measured 20 cm below the top of the vats. Fermentation may also occur in sewers and liquid manure pits.

Deaths by intentional CO_2 intoxication are rare. Generally, deaths are suicides by intentional inhalation of automobile exhaust gases (9,10). To the best of our knowledge, this case is the first describing this manner of suicide in the modified atmosphere of an apple packaging room attributed to asphyxiation caused by CO_2 intoxication and notably O_2 depletion.

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References

1. Gill JR, Ely SF, Hua Z. Environmental gas displacement: three accidental deaths in the workplace. Am J Forensic Med Pathol 2002;23:26–30.
2. Nelson L. Carbon dioxide poisoning. Emerg Med 2000;32:36–8.
3. Ikeda N, Takahashi H, Umetsu K, Suzuki T. The course of respiration and circulation in death by carbon dioxide poisoning. Forensic Sci Int 1989;41:93–9.
4. http://www.adrenaline112.org/urgences/DUrge/DPhys/AccBioch.html. Accessed July 31 2008.
5. Louis F, Guez M, Le Bacle C. Intoxication par inhalation de dioxyde de carbone. Documents pour le Médecin du Travail 1999;79:179–94.
6. http://www.champagne-ardenne.cci.fr/fr/strategies/pagesco/pdf/conservation1.pdf. Accessed July 31 2008.
7. Yamazaki M, Islam MN, Ogura Y, Honda K, Tsuchihashi H, Nishioka H. An autopsy case of carbon dioxide intoxication. Nihon Hoigaku Zasshi 1997;51:446–51.
8. Guillemin MP, Horisberger B. Fatal intoxication due to an unexpected presence of carbon dioxide. Ann Occup Hyg 1994;38:951–7.
9. Schmunck GA, Kaplan JA. Asphyxial deaths caused by automobile exhaust inhalation not attributable to carbon monoxide toxicity: study of 2 cases. Am J Forensic Med Pathol 2002;23:123–6.
10. Atkinson P, Langlois NE, Adam BJ, Grieve JH. Suicide, carbon dioxide, and suffocation. Lancet 1994;344:192–3.

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