Mass Casualties from Acute Inhalation of Chloramine Gas

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Mass exposure to chloramine gas has not been reported. We report two groups of 36 patients (72 total) suffering from acute inhalation of chloramine gas. Chloramine gas is produced from mixing common household cleaning agents containing sodium hypochlorite (bleach) and ammonia. The first mass casualty event occurred when 36 male soldiers were exposed during a “cleaning party” in their barracks. Ten days later, 36 female soldiers were exposed in a similar manner and presented to our emergency department. In each event, commonly available cleaning agents—liquid bleach and ammonia—were mixed together, liberating toxic chloramine gas. Nebulized sodium bicarbonate solution has been suggested for treatment of chlorine gas inhalation, but no report of nebulized sodium bicarbonate for treatment of chloramine gas inhalation injury exists. In our series, 22 patients exposed to chloramine gas were treated with a nebulized solution of 3.75% sodium bicarbonate. This treatment made no significant statistical or clinical difference in outcome. We present the largest case series of patients presenting to an emergency department for treatment of acute inhalation of chloramine gas.

Introduction

Although chlorine gas inhalation injuries have been extensively reported, little information exists regarding inhalation injuries from chloramine gas. Homemakers, custodians, and industrial employees often mix domestic cleaning agents without being aware of the dangers. Mixing solutions of sodium hypochlorite (NaOCl, bleach) and ammonia (NH₃) produces monochloramine (NH₂Cl) and dichloramine (NHCl₂) gas.¹ These toxic fumes cause tearing, rhinorrhea, cough, dyspnea, and nausea. It is proposed that chloramines combined with moisture from the respiratory tract decompose to hypochlorous acid (HOCI) and free ammonia gas.¹⁻³ Hypochlorous acid combines with moisture, forming hydrochloric acid (HCl) and toxic nascent oxygen.² The oxygen radical is a strong oxidizing agent that, along with the acids and ammonia, causes corrosive effects and cellular injury. This can lead to pneumonitis and edema.¹⁻³

Nebulized sodium bicarbonate solution (NaHCO₃) has been suggested for the treatment of acute chlorine gas inhalation.⁴⁻⁶ This treatment is based on anecdotal reports of its efficacy. No report of its use in treating the slightly different, but likely more common, noxious chloramine gas exists (MEDLINE, 1966–1996).

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Case Series

Exposure 1

Thirty-six male soldiers, aged 18 to 26 years, presented en masse to the emergency department after being exposed to chloramine gas. The incident occurred during a “cleaning party” at a basic trainee dormitory on a large military installation, where liquid bleach and ammonia had been mixed in toilet bowls. A majority of patients reported a noxious odor, instant throat irritation, burning, and choking. Other symptoms reported included shortness of breath, cough, eye irritation, rhinorrhea, and chest pain.

Triage was performed by emergency physicians and nurses with particular attention to initial pulse oximetry readings. No patient was noted to be hypoxic; all room air oxygen saturation readings were greater than 94%. Four physicians on duty treated patients for symptomatic exposure with oxygen or with a nebulized solution of sodium bicarbonate. Treatment was based on physician preference only. Twenty-two of 36 patients received nebulized 3.75% sodium bicarbonate solution. The solution was made by diluting 2 cc of standard 7.5% intravenous sodium bicarbonate solution with 2 cc of normal saline and delivered by hand-held nebulizer with oxygen. The other 14 patients were treated with oxygen alone.

One patient of the 22 treated with nebulized sodium bicarbonate required hospitalization for persistent shortness of breath, cough, and throat irritation. His physical examination revealed cough, conjunctival injection, and rhinorrhea. His vital signs were normal except for a respiratory rate of 28 breaths per minute. His admission arterial blood gas taken on room air oxygen was: pH 7.428, pCO₂ 33.5, pO₂ 74.7, HCO₃ 22.6, with 95.5% saturation. His chest radiograph was normal. He had persistent symptoms after nebulized sodium bicarbonate, nebulized β-agonist, and intravenous steroid therapies. He was discharged the next day after an uneventful admission. All remaining patients, 35 total, were discharged from the emergency department.

This incident was known to the post’s fire department, and a report was made to Environmental Engineering. Despite these warnings, a repeat event occurred shortly thereafter.

Exposure 2

Ten days after the first mass exposure, a similar incident occurred involving 36 female soldiers, aged 18 to 30 years. Again, the incident occurred in a trainee dormitory during a cleaning party, and the agents involved were standard cleaning solutions of bleach and ammonia. The agents were mixed in unmeasured quantities into toilet bowls and buckets, immediately liberating a noxious gas. Presenting complaints and symptoms included shortness of breath, cough, eye and throat irritation, and chest tightness.

Patients were treated with supportive care only. No patients received nebulized sodium bicarbonate therapy. All patients,
except one, did well and were discharged from the emergency department. The admitted patient was a 20-year-old female who presented with wheezing, shortness of breath, respiratory stridor, coughing, rhinorrhea, and severe eye irritation. Her pulse oximetry was 99% on room air, and her vital signs were normal except for a respiratory rate of 32 breaths per minute. An arterial blood gas test was not performed. Her chest radiograph was normal. Treatment included humidified oxygen, nebulized β-agonist, and intravenous steroids. Her hospitalization was complicated by tracheobronchitis, and a subglottic lesion was noted by fiber-optic laryngoscopy. The patient required intensive care observation for several days but suffered no long-term complications from her exposure.

Discussion

Chloramines are produced from the mixing of the common household cleaning products bleach (NaOCl) and ammonia (NH₃).⁴ On contact with mucosa, chloramines decompose to free ammonia gas and hypochlorous acid (HOCI).¹⁻⁴ Hypochlorous acid combines with moisture, forming hydrochloric acid (HCl) and liberating nascent oxygen, which is a potent oxidizing agent capable of causing most of the cellular injury¹⁻³ (see Fig. 1). The corrosive effects of ammonia and hydrochloric acid also contribute to chloramine-induced respiratory tract damage.²

Inhalation of low concentrations of chloramine produces only tearing, rhinorrhea, burning of oral membranes, and cough.⁷ Physical examination in cases of mild exposure is usually normal, with occasional wheezes and decreased breath sounds possible. Pulmonary function testing after exposure to chloramine gas has revealed both restrictive and obstructive disease as well as diffusion abnormalities.⁵⁻¹⁰

Severe exposure to chlorine gas may cause tracheobronchitis, pulmonary congestion, patchy pneumonitis, alveolar edema, or pneumomediastinum.¹⁻³,¹¹,¹² One report of two fatalities from chlorine gas poisoning exists.¹³ Two cases of serious injury after brief exposure to vapors from solid chlorine compounds have been described.¹⁴ More than 1 million casualties and 100,000 deaths during World War I have been attributed to chlorine, phosgene, and mustard gas toxins.¹⁵

Although recognized, case reports of clinically significant chloramine gas exposure are more rare. Two case reports of chloramine-induced pneumonitis resulting from mixing of household cleaning agents, four patients total, are the only reports of serious injury.²,¹⁶ A review of 216 cases of home exposures to chlorine or chloramine gas found only 16 patients to have symptoms past 6 hours and only 1 patient required admission. This was a review of cases reported to a Regional Poison Information Center, and of the 71 patients presenting for medical care, none received nebulized sodium bicarbonate.¹⁷

Decontamination of acute chloramine gas inhalation injury begins with removal from the offending environment. If outside, evacuation of casualties to a position upwind from the contaminating source is ideal. Removal of clothing, decontamination showers, and mucous membrane irrigation is beneficial in severe cases. Supportive therapy,⁶,¹⁸,¹⁹ humidified oxygen,⁶,²⁰ and bronchodilators⁶,²⁰ have been advocated for the treatment of mild toxic inhalation of hypochlorites and related agents. Positive end-expiratory pressures and bronchoscopy have been outlined for the treatment of potentially lethal pulmonary edema.²⁰

Nebulized sodium bicarbonate solution has been suggested as a treatment agent for acute inhalation of chlorine gas, although human data regarding bicarbonate therapy is entirely anecdotal.⁴,⁵,⁶,²¹ The use of a 5% sodium bicarbonate nebulized solution for burning pain in the chest has been suggested.⁴ A 2-year retrospective review from the University of Louisville examined 86 cases of chlorine gas inhalation from 49 different medical facilities. All cases were treated with 3 ml of 8.4% sodium bicarbonate mixed with 2 ml of normal saline (producing 5 ml of 5% sodium bicarbonate solution), delivered by nebulizer. Sixty-nine patients (80%) were treated and discharged. No control over other therapeutic modalities such as inhaled bronchodilator, inhaled steroids, systemic steroids, or intravenous theophylline was used. The investigators concluded that nebulized sodium bicarbonate was safe and potentially beneficial, although prospective trials are needed.⁵

Relief of symptoms in three male patients exposed to a swimming pool chlorine gas leak after 3.75% nebulized sodium bicarbonate therapy has been reported. The author acknowledges that this therapy cannot routinely be recommended because of lack of clinical studies.²¹ There is no evidence of efficacy through controlled studies to advocate such therapy.

A single animal-model study in sheep exposed to chlorine gas for 4 minutes and then randomized to nebulized normal saline control or 4% sodium bicarbonate therapy demonstrated a higher pCO₂ and lower pO₂ in the control group. The authors report that sodium bicarbonate did not worsen outcome as measured by 24-hour mortality and postmortem pathologic evaluation and may actually improve arterial blood gas values in sheep.²² No data exist regarding the use of nebulized sodium bicarbonate therapy for treatment of acute chloramine gas inhalation injury.

Chemical products with potential human hazard are regulated by the U.S. Consumer Product Safety Commission.²³ Such consumer products have labeling requirements from the Federal Hazardous Substances Act.²⁴ Labels on consumer products containing 5% or more hypochlorite must include warnings against mixing with acids and other household chemicals.²³,²⁴

Standard household bleach is a 5.25% sodium hypochlorite solution. Labels of products containing 3% or more ammonia must warn against mixing with chlorine-type bleaches or other household chemicals.²³,²⁴

Our experience represents the largest report of acute chlo-
mine inhalation injuries presenting to an emergency facility. This is the first report of the use of sodium bicarbonate therapy for treatment of chloramine inhalation injury. One of 22 patients treated with nebulized sodium bicarbonate was admitted, as was 1 of 50 patients treated without nebulized sodium bicarbonate. All other patients did well and were discharged from the emergency department. The exposures appeared to be mild, with only 1 of 72 patients developing prolonged symptoms and complications. Treatment was based on physician preference in a nonrandomized fashion, and the groups were not matched, so no statistical conclusion can be drawn. These limitations are similar to those of other reports of the use of bicarbonate therapy in the treatment of chloramine inhalation injuries.

Dormitories and barracks are often stocked with potentially hazardous cleaning agents. Accidents do occur and efforts should be made to reinforce proper use of such chemicals and to encourage education of personnel regarding the hazards of mixing chemicals. Through identification of potential hazards and education of proper usage, life-threatening medical emergencies may be avoided.

Summary

Bleach and ammonia are common cleaning agents that yield a potentially lethal combination when mixed. Chloramine gas and its by-products are known irritants to mucous membranes and the respiratory tract. There exists a high likelihood that an emergency physician will encounter a patient or patients with acute chloramine gas inhalation.

Although nebulized sodium bicarbonate therapy is reported in chlorine gas inhalation, no report of its use in acute chloramine inhalation exists. We report mass casualties from acute inhalation of chloramine gas and describe the use of nebulized sodium bicarbonate. No statistical significance can be drawn from this case series. Randomized, controlled studies are indicated to define the possible role of nebulized sodium bicarbonate in the treatment of chlorine and chloramine gas inhalation injuries.

It is indeed unfortunate that the standard reporting of the first "sentinel" event did not prevent the second exposure. Awareness of the potential hazards of mixing cleaning agents, identification of these hazards, and education of personnel is necessary to prevent inhalation injuries.

References

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