Pneumonitis and Respiratory Failure Secondary to Civilian Exposure to a Smoke Bomb in a Partially Enclosed Space

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ABSTRACT

Smoke grenades are used during drills, police and military exercises, and crowd control. We report on a 25-year-old man who was exposed to a Superior 3C smoke bomb. He was initially stable but developed respiratory distress after 3 days and ultimately developed pulmonary fibrosis with marked loss in pulmonary function. The Superior 3C smoke bomb is similar in composition to the British Military's L83A1/2 and L132A1 and the US M18 smoke grenades, all commonly used as multipurpose smoke-producing devices for combat and training. They are primarily composed of zinc oxide and hexachloroethane, the combustion of which produces zinc chloride. These devices are safe when used properly in open air but can cause significant morbidity in an enclosed space. This case emphasizes the potential hazards of using smoke bombs even in semienclosed spaces and the potential delay in the development of significant pulmonary complications.

KEYWORDS: *smoke bomb; pneumonitis; pneumomediastinum; pneumothorax; pulmonary fibrosis; zinc chloride*

Introduction

The civilian C3 smoke bomb and the US M18 smoke grenade are similar in composition function. The M18 colored-smoke grenade is commonly used in all branches of the military, in conventional and Special Operations forces, for many purposes, including creating concealment, simulating battle conditions and other gasses, such as CS and chemical weapons. It is also used as a location marker for aircraft and ground forces.[1] Similar devices, such as the one used in th case reported in this article, are also used as crowd-dispersal agents by law enforcement.[2] These devices are safe when used in an open space, causing only mild upper respiratory irritation; however, when used in an enclosed space, they may be highly dangerous and can even result in death.[2] US Army regulations state the M18 should not be used in enclosed spaces.

With such a wide variety of uses, the number of military personnel exposed to these devices each year is extremely large. Although most of these exposures occur in relatively safe, open-air conditions, there are multiple case reports of patients exposed in confined areas, often with significant morbidity (Table 1).[3–6] Statistics on such enclosed exposures are not tracked, but with such a high volume of use, they are likely underreported.

TABLE 1 *Summary of Case Reports Related to Zinc Chloride Exposure*

First Author	Summary
Zerahn[6]	Thirteen soldiers were exposed to zinc chloride during a combat exercise when wind blew in and trapped the smoke within the enclosed area. Despite sparse initial symptoms, they developed quantifiable damage to lung parenchyma 4 weeks after exposure.
Hsu[5]	Twenty soldiers were exposed for 5–10 minutes to dense fumes without mask protection in an enclosed tunnel. At least five developed acute respiratory distress syndrome.
Gil[4]	A 21-year-old patient inhaled zinc oxide/hexachloroethane when trapped in a small bathroom with the device. Fever and tachypnea developed 6 hours later. Radiologic evaluation showed mixed interstitial-alveolar bilateral infiltrates. Despite supportive care, the patient died of multiorgan failure 9 days later.
Chian[3]	A 23-year-old man exposed to smoke from a grenade within an enclosed tunnel for 10–15 minutes without protective breathing apparatus developed acute respiratory distress syndrome complicated by bilateral pneumothorax and pneumomediastinum 48 hours after inhalation. He was reported to have survived after receiving extracorporeal life support and corticosteroids.

Case Presentation

While evading capture by police, a 25-year-old man attempted to hide in a semi-enclosed storm drain. To encourage voluntary self-extrication from the storm drain with a minimum of violence and risk, the police officers used a Superior 3C smoke bomb. He continued to resist police capture within the confines of the drain for 20–30 minutes until he emerged, coughing and short of breath, and was taken to a local emergency department for evaluation. He initially complained of burning eyes, throat irritation, and cough. He denied past medical history, allergies, tobacco or recreational drug use, but admitted to social ethanol consumption. He had emigrated from Mexico and worked in construction. The patient was unaware of any previous occupational or environmental exposures prior to his arrival in the United States. He was subsequently treated with symptomatic care, improved, and released into police custody, with a prescription for antibiotics and prednisone for presumed bronchitis.

He was brought to another emergency department 3 days later, now with shortness of breath and pleuritic chest pain.

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Vital signs at that time were heart rate, 140/min; blood pressure, 100/60mmHg; respiratory rate, 40/min; temperature, 103.6°F (39.8°C), and pulse oximetry, 55% on room air. He was awake and alert, visibly in severe respiratory distress, with crepitus over the anterior chest and neck. Cardiac examination revealed tachycardia without murmurs, rubs, or gallops. Pulmonary auscultation demonstrated coarse breath sounds with loud bilateral crackles. The remainder of his physical examination was without abnormal findings.

The patient was intubated for respiratory failure. His chest radiograph and computed tomography imaging exhibited bilateral, diffuse interstitial infiltrates consistent with acute respiratory distress syndrome, pneumomediastinum, and pneumothorax with subcutaneous emphysema (Figure 1), which required bilateral tube thoracotomies. Echocardiogram revealed no cardiac abnormalities. A bronchoscopy with sputum samples was significant for numerous neutrophils. All cultures (i.e., blood, urine, and bronchoalveolar lavage) were negative for bacterial, viral, fungal, pneumocystis, and legionella infections. A screen for human immunodeficiency virus was also negative.

The patient ultimately required mechanical ventilation for 42 days and a percutaneous tracheostomy tube was placed on day 21. The patient was discharged 56 days after admission with persistent dyspnea and bilateral pulmonary infiltrates consistent with early pulmonary fibrosis. Outpatient follow-up 3 weeks after discharge revealed residual shortness of breath and pulmonary function tests with 30% of his lung capacity remaining.

Discussion

The civilian C3 and military M18 smoke bombs both use hexachlorethane and zinc oxide, and differ only in packaging and source of ignition.[7] When ignited, calcium silicide reduces zinc oxide, which, in turn, reacts with hexachlorethane, forming zinc chloride, calcium carbonate, free carbons, and silica. Additional minor products of combustion include small amounts of phosgene, tetrachloroethane, carbon tetrachloride, and carbon monoxide.

Zinc chloride readily combines with water in the atmosphere and in the respiratory tract to create hydrochloric acid and zinc oxychloride. Because of the small particle size, it can penetrate deep into the respiratory tract and cause severe irritation and pulmonary epithelial necrosis within the alveoli.[8] For zinc chloride, the threshold limit value and immediately dangerous to life and health value are 1mg/mm^3 and 50mg/mm^3, respectively, and animal studies have demonstrated pulmonary edema, alveolar hemorrhage, localized bulbous emphysema, and alveolar cell carcinoma with exposure.[9]

Hexachlorethane is also a potentially toxic chemical, reported to be a cause of hepatic failure.[10] The patient presented in this case did not experience this adverse effect.

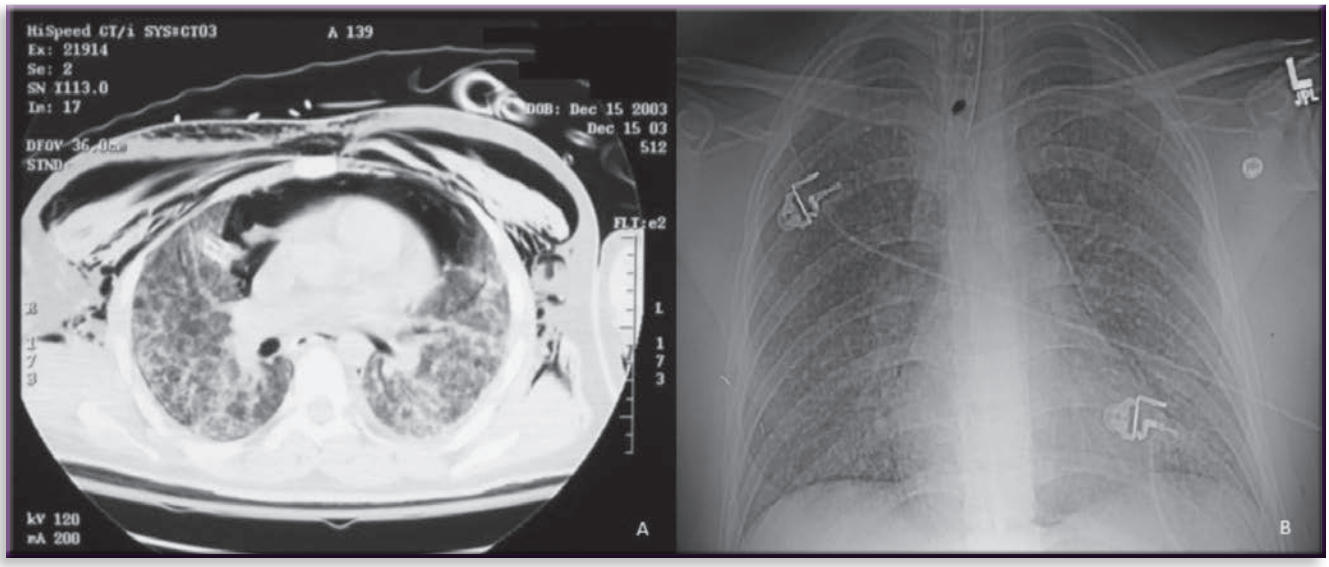
Conclusion

This case highlights the dangers of these smoke-bomb chemicals in partially open environments, which may be erroneously considered safe, as well as the potential delay of severe symptomatology and respiratory distress. Previous cases have only described significant morbidity after enclosed exposure, and so a mild presentation after semi-open exposure may cause a practitioner to erroneously assume a nonconsequential incident. However, because significant lung injury can be delayed days to weeks after the initial exposure, the patient may be put at considerable risk if they are too soon without adequate follow-up instruction. Medical providers and medics should consider close observation of patients with mild symptoms during the first days after exposure and issue clear return precautions to the patient for any worsening symptoms. Finally, military leadership, operational medical providers, and team medics should all be aware of the potential hazards of the M18 and similar devices when planning training exercises, because they have the potential to cause significant morbidity even in semi-open environments.

Disclaimer

The view(s) expressed herein are those of the authors and do not reflect the official policy or position of the US Army Medical Department, the US Army Office of the Surgeon General,

FIGURE 1 **(A)** *Computed tomography scan of the thorax showing bilateral diffuse infiltrates, pneumomediastinum, and subcutaneous emphysema.* **(B)** *Chest radiograph showing pneumomediastinum and bilateral pulmonary infiltrates.*



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Author Contributions

All authors contributed to the writing of this manuscript and approved the final version.

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