Chlorine poisoning caused by improper mixing of household disinfectants during the COVID-19 pandemic

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Research

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Abstract

Background

During the coronavirus disease 2019 (COVID-19) pandemic, many people have abused and misused disinfectants, leading to many poisoning incidents. However, there are few clinical case reports of poisoning caused by mixed household disinfectants. This study summarized the clinical characteristics and treatment effects of chlorine poisoning caused by improper mixing of hypochlorite bleach with acidic cleaning agents to improve the understanding of the disease.

Methods

We retrospectively analyzed the basic data, clinical symptoms, treatment methods, imaging, and other clinical data of seven patients with chlorine poisoning, caused by an improper mixture of hypochlorite bleach and acidic cleaning agents, who were admitted to the National Army Poisoning Treatment Center.

Results

The seven patients (three men and four women) had an average age of 48.8 years (18–67 years). The average poisoning time (time from exposure to poison to treatment) was 57 h (4–240 h). All seven patients were involved in cleaning bathrooms during the COVID-19 pandemic. Chest computed tomography scans showed bilateral lung effusions or inflammatory changes in five patients and no obvious exudation or inflammatory changes in two. The partial pressure of oxygen decreased in six patients, and respiratory failure occurred in one. Five patients had different degrees of increase in white blood cell count. For treatment, humidified oxygen therapy, non-invasive mechanical ventilation, intravenous corticosteroids, inhaled hormone, bronchial spasmolytics, antibiotics, and other symptomatic and supportive treatments were provided. The average length of hospital stay was 7 days (4–9 days). All seven patients recovered and were discharged.

Conclusions

Improper mixing of house disinfectants during the COVID-19 pandemic may cause damage to the respiratory system due to chlorine poisoning. Corticosteroids may improve lung exudation in severe cases. Additionally, symptomatic supportive treatment should be performed early.

Background

There are many types of household disinfection products, and the incidence of poisoning related to these products, caused by misuse and accidents, remains high [1–4]. Among them, inhalation-induced poisoning accounts for a large proportion of cases and often causes serious injuries [3, 4]. In China, 84 disinfectants (with sodium hypochlorite as the main component) and toilet cleaner (diluted hydrochloric acid) are widely used in households, and there are many poisoning incidents involving these products [4]. The use of household disinfectants increased significantly during the coronavirus disease 2019 (COVID-19) pandemic [5–7]. It is common for people to use disinfectants incorrectly [6]. Furthermore, some people think that household disinfectants can eliminate the novel coronavirus, and household disinfection is inappropriately conducted [2, 7, 8]. Household disinfectants may cause toxic reactions and produce toxic gases, including chlorine [2–4, 9]. Chlorine exposure is usually caused by accidental release of chlorine vapor from swimming pools, improper mixing of hypochlorite bleach and acid cleaners, school chemical experiments, and industrial or chemical transportation accidents [9–13]. Due to its high toxicity and common availability, chlorine gas has also been used in terrorist attacks and chemical warfare agents [11, 12]. There are a few clinical case reports on acute chlorine inhalation poisoning caused by improper mixing of household disinfectants and toilet cleaners [3]. Yet, clinicians lack a deep understanding of the possible clinical manifestations and prognosis of such patients. Here, we summarized the clinical data of seven patients admitted to our center during the COVID-19 pandemic with acute chlorine inhalation poisoning caused by improper mixing of disinfectants and toilet cleaners. The summary could help improve a clinician's ability to treat future cases.

Methods

Study design and population

We collected and retrospectively analyzed the clinical data, diagnosis, and treatment of seven patients with acute chlorine inhalation poisoning caused by improper mixing of disinfectants and toilet cleaners who were admitted to the National Army Poisoning Treatment Center from March 2020 to September 2021. All patients had a clear history of inhaling chlorine gas, an irritant, produced by improper mixing of toilet cleaners and any of the 84 disinfectants widely used in Chinese households. The collected data included the patients' baseline data: sex, age, underlying disease, poisoning time, and cause of poisoning; clinical manifestations: main symptoms, related laboratory tests, and imaging data; and diagnosis and treatment process: treatment methods, hospitalization days, prognosis, and follow-up prognosis. All patients provided informed consent, and the retrospective study design was approved by the appropriate ethics review board of our hospital.

Statistical analyses

Descriptive statistics were used to summarize the data; results are reported as the mean (minimum–maximum). No imputation was performed for missing data. Analysis was performed using Stata 15.1 software.

Results

Baseline characteristics

The patients included three males and four females, with an average age of 48.8 years (18–67 years). All patients confirmed that they mixed two kinds of household disinfection products to clean household items or toilets and saw the production of yellow-green gas; the diagnosis of poisoning due to chlorine gas inhalation was clear. The average poisoning time (time from exposure to poison to treatment) was 57 h (4–240 h). All patients' poisoning occurred while disinfecting a room during the COVID-19 pandemic. The patients' data are summarized in Table 1.

Table 1
Baseline characteristics at admission and major treatments

	Age, (y)	Sex	Comorbidities	Initial symptoms	Admission time	PaO ₂ / FI _O 2	Computed Tomography	Major treatments
1	60	F	Hypertension, hyperthyroidism	Breathlessness, difficulty breathing, headache, dizziness	3h	318.10	Bilateral lung effusions	Humidified oxygen; methylprednisolone(80mg for 3d, 40mg for 3d); inhaled budesonide and bromhexine; cefmetazole anti-infection;
2	61	M	None	Breathlessness	10d	372.38	Bilateral interstitial exudations	Humidified oxygen; methylprednisolone(80mg for 3 d, 40mg for 3 d); inhaled budesonide and bromhexine; azithromycin anti-infection;
3	60	F	None	Fatigue, breathlessness, coughing, choking of the pharynx, dizziness, headache, transient unconsciousness, urinary incontinence	24h	215.52	Bilateral lung effusions	Humidified oxygen; methylprednisolone (80mg for 3 d, 40mg for 3 d); inhaled budesonide and bromhexine; cefmetazole anti- infection;
4	18	F	None	Dizziness, coughing, nausea, vomiting	6h	396.19	Striped shadow under the pleura of the right lung	(pre-hospital) Dexamethasone(10mg); humidified oxygen; mthylprednisolone(40mg for 3 d);
5	56	M	Smoking history for 30 years	Chest tightness, breathlessness	12h	342.86	Bilateral lung emphysema and bullae	Humidified oxygen; inhaled budesonide and bromhexine; methylprednisolone(80mg for 3 d, 40mg 3 d); moxifloxacin anti- infection;
6	20	M	Smoking history for 2 years	Chest tightness, cough, choking in the pharynx, breathlessness, difficulty breathing	17h	198.62	Bilateral lung effusions	Non-invasive mechanical ventilation; methylprednisolone (80mg for 5 d, 40mg for 2 d); inhaled budesonide and bromhexine; Moxifloxacin anti- infection;
7	67	F	Hypertension history for 24 years	Coughing, breathlessness	4d	210.34	Increased texture of blood vessels in bilateral Lung and multiple patchy change under the pleura;bilateral pneumonia changes;	Methylprednisolone(80mg for 3 d, 40mg for 3 d); inhaled budesonide and bromhexine; moxifloxacin anti-infection;
F:female; M:male; y:years; d:days; h:hours; Admission time:time from symptom onset to admissions								

Clinical and clinicopathological symptoms

The clinical manifestations and severity of poisoning due to intoxication time, absorption, age, and individual physiques differed the among patients included in this study. Among the seven patients, six had mild symptoms and one had severe symptoms.

Additionally, six had breathlessness, two had dyspnea, three had a headache, three had dizziness, three had a cough, two had pharyngeal discomfort, one had fatigue, one had nausea, and one had vomiting symptoms. One patient developed transient unconsciousness (recovered consciousness in approximately 1 min) and urinary incontinence. The patients' symptoms are shown in Table 1. The laboratory test results on admission showed an average white blood cell count of $13.61 \times 10^9/L$ ($3.83\text{--}19.05 \times 10^9/L$). The average oxygen partial pressure was 68.17 mmHg (57.6–83.2 mmHg), and the average oxygenation index was 293.43 mmHg (198.62–396.19 mmHg). Among the patients, three had toxic lung injury (oxygenation index <300 mmHg), one had an oxygenation index <200 mmHg, six had hypoxemia, one had type I respiratory failure, and five had chest computed tomography (CT) scans showing bilateral lung effusions or inflammatory changes. Chest CT scans of two of the patients showed no obvious exudation or inflammatory changes. The chest CT image of the heaviest patient (patient 6 in Table 1) is shown in Figure 1. Supplementary Material 1 shows the chest CT images of the other patients.

Treatment, prognosis, and follow-up

Six of the patients received humidified oxygen, and one patient was treated with non-invasive mechanical ventilation. In addition to anti-inflammatory glucocorticoids (including intravenous methylprednisolone and inhaled hormone) (see Table 1 for specific dosages), to relieve bronchospasm and reduce phlegm, antioxidants and antibiotics were used to maintain the acid-base electrolyte balance and prevent bacterial infection, respectively. After treatment, all the patients' conditions improved, and repeat chest CT scans showed significant improvement (see Figure 1 and supplementary materials). The average length of hospital stay was 7 days (4–9 days). All patients recovered and were discharged, and no symptom recurrence was observed after follow-up.

Discussion

The cases we reported described chlorine poisoning caused by improper mixing of toilet cleaners and any of the 84 disinfectants commonly used in Chinese households during the COVID-19 pandemic. The effective ingredients of these products include diluted hydrochloric acid and sodium hypochlorite. Mixing both these solutions causes a chemical reaction that produces chlorine gas. Among the seven patients with chlorine poisoning, one had severe symptoms. The chest CT scan showed significant bilateral lung effusion, and the patient's blood gas analysis indicated type I respiratory failure. However, after active treatment, the condition of all patients improved significantly. This highlights the importance of early detection, diagnosis, and treatment and presents our valuable experience in treating patients with chlorine poisoning.

Chlorine is a toxic and irritating gas [9, 14]. Due to the different concentrations, intoxication times, and individual sensitivities of the human body, acute chlorine gas inhalation can cause varying degrees of damage to the human body and even be life-threatening [11, 15–17]. After inhalation through the respiratory tract, the chlorine gas reacts with moisture on the mucosal surface of the respiratory tract to generate hypochlorous and hydrochloric acid [11, 15]. Hypochlorous acid can be decomposed into hydrochloric acid and new ecological oxygen, causing local irritation and corrosion [4]. As chlorine can combine with reactive oxygen species and other airway fluid components to form a variety of highly active oxidants, the airway epithelium may immediately undergo direct oxidative damage [11, 15]. Additionally, the migration and activation of inflammatory cells, such as neutrophils, in the airway epithelium and the subsequent release of oxidants and proteolytic enzymes may cause further damage to the epithelium [15]. Therefore, chlorine poisoning can cause bronchospasm and bronchitis, and in severe cases, it can cause pulmonary edema and may be accompanied by damage to other organ systems, such as the cardiopulmonary and nervous systems [9, 18, 19]. Acute chlorine poisoning is characterized by acute respiratory system damage [17]. All seven patients in our study had respiratory symptoms, such as wheezing, dyspnea, and pharyngeal discomfort. Imaging indicated varying degrees of lung injury. Most of the patients had different degrees of increase in white blood cell counts and high-sensitivity C-reactive protein levels, suggesting an acute inflammatory response. The direct interaction of chlorine and acute inflammatory response may lead to acute toxic lung injury and its complications [15]. One patient had transient unconsciousness, suggesting that chlorine may have a toxic effect on the human nervous system [19], which is consistent with what is reported in the literature [19].

Current treatment measures in response to acute chlorine inhalation poisoning, which mainly causes toxic lung injury and systemic inflammation, include humidified oxygen therapy, use of corticosteroids (intravenous and inhaled), airway antispasmodic drugs, antioxidants, and inhaled sodium bicarbonate [9, 17]. Recent studies suggest TRPV4 inhibitors, dimethylthiourea, and rolipram as therapeutic options, although these have not been clinically used [9, 17]. Furthermore, there are doubts about the efficacy of glucocorticoids among these treatment measures, and currently, extensive studies to verify the findings are scarce [9]. Our study used

the treatment strategy of intravenous methylprednisolone combined with inhaled hormone and found that the effect of this treatment on heavier patients was significant. Corticosteroid therapy can significantly reduce inflammatory exudation caused by chlorine gas, and our study presents clinical experience on the use of corticosteroids for the treatment of chlorine poisoning [9]. Current treatment measures for hypoxemia and respiratory failure caused by chlorine poisoning include humidified oxygen therapy, non-invasive mechanical ventilation, invasive mechanical ventilation, and extracorporeal membrane oxygenation therapy [9, 17, 20]. In this study, six patients with hypoxemia received oxygen therapy and one critically ill patient received non-invasive mechanical ventilation; all patients' breathing conditions significantly improved. None of the patients received invasive mechanical ventilation. Therefore, with the treatment experience of our seven patients, we conclude that the treatment should be based on the principles of inflammation control; antioxidant therapy; protection of lung function; prevention and treatment of pulmonary edema; protection of the heart, liver, brain, kidney, and other essential organ functions; and improvement of oxygen delivery. In terms of treatment, recommended emergency intervention steps include 1) immediately move away from the scene to a place with fresh air, keep the respiratory tract unobstructed, and provide timely and effective oxygen therapy; 2) provide non-invasive mechanical ventilation or even invasive mechanical ventilation when necessary to improve respiratory conditions and increase oxygen delivery; and 3) administer early, adequate, short-term corticosteroid therapy to improve pulmonary edema. In this study, 40–80 mg/day of methylprednisolone was administered for 3–7 days. Other treatments included antispasmodic and anti-asthmatic symptomatic treatment, including supporting essential organ functions, nutritional support, maintenance of water and electrolytes, and acid-base balance. In principle, it is not recommended to use antibiotics to treat acute chlorine inhalation poisoning, but it was administered to prevent opportunistic bacterial infections. Appropriate antibiotics should be administered to treat infections timeously [17]. To prevent infection, we administered antibiotics to all patients in this study. However, the advantages and disadvantages of using corticosteroids and antibiotics to prevent infection in acute chlorine inhalation poisoning should be further investigated [17]. Additionally, some researchers have attempted to atomize bicarbonate to treat the acidic environment of the airways and lungs caused by chlorine poisoning, but its dosage is uncontrollable and the benefits from the perspective of lung physiology are unclear [17]. Furthermore, new treatment methods (including TRPV4 antagonists, dimethylthiourea, and rolipram) are still experimental.

Conclusions

Overall, there are no specific antidotes and effective treatment measures for acute chlorine inhalation poisoning, and comprehensive supportive treatment is the primary treatment method. Additionally, corticosteroids may improve lung exudation. Therefore, it is crucial to understand and prevent acute chlorine inhalation poisoning. It has been very important to use household disinfectants correctly to prevent chlorine inhalation poisoning during the COVID-19 pandemic. Hydrochloric acid and sodium hypochlorite disinfectant products, such as commonly used disinfectants and toilet cleaners, should not be mixed. Should chlorine inhalation poisoning occur, timely ventilation and hospital medical treatment are required.

Abbreviations

CT: computed tomography; COVID-19: coronavirus disease 2019

Declarations

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Written informed consent for publication of the clinical details and clinical images was obtained from the patient.

Authors' contributions

Lin Guodong, Tong Huashen, Qiu Zewu and Dong Jianguang conceived the study, designed the trial, and obtained research funding. Peng Xiaobo, Lu Xiaoxia and Liu Zhongying supervised data collection and managed the data, including quality control. Qiu Zewu and Dong Jianguang provided statistical advice on study design and analyzed the data. Lin Guodong and Wu Jieyi drafted the

manuscript, and all authors contributed substantially to its revision. Tong Huashen, Qiu Zewu and Dong Jianguang take responsibility for the paper as a whole.

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Figures

Figure 1

Chest CT image of the heaviest patient.

Supplementary Files

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