Adverse Respiratory Health Effects of Tear Gases

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Abstract:

Background and objective: Tear gases commonly used for crowd control purposes can cause multi-organ system derangement and transient disability. This study collects some pieces of evidence of respiratory system toxicity from inadvertent use of tear gases, both immediate and long-term effects.

Methods: The medical records of patients injured from tear gases exposure during the 2013-2014 political turmoil were reviewed. Clinical and laboratory data of other victims seeking medical attention at mobile health station nearby the demonstration site were also collected.

Results: There were 37 victims, none had preexisting respiratory disease, 4 had history of atopy, and 18 were active smoker. The mean exposure time was 7.7 hours. Two cases of chemical bronchiolitis and pneumonitis were identified. In the field study among 35 cases, almost all of them had persistent cough and sputum production. Nasopharyngeal inflammation could be observed in 29 cases (83%). Abnormal spirometry was encountered in 8 patients (23%), 3 with obstructive ventilatory defect, and 5 with small airway obstruction. Airway hyperresponsiveness was demonstrated in one case in which also had obstructive ventilatory defect.

Conclusions: Objective evidence of acute and late notorious effects on human respiratory system after heavy exposure to tear gases has been demonstrated, and should be seriously considered for its future use.
Introduction

Tear gas is a term for the family of chemical compounds that can cause temporary disablement, four common agents are ortho-chlorobenzylidenemalonitrile (CS), omega-chloroacetophenone (CN), 10-chloro-5, 10-dihydrophenarsazine, and alpha-bromo-alpha-tolunitrile.1 Tear gases have been employed widely as a mean of controlling mass during the demonstration. In general, if used correctly, the noxious effects of exposure are transient and no long-term consequences are expected. However, firing and throwing tear gases directly and repeatedly to the crowd, could result in penetrating trauma from the containments, chemical skin burn from direct contact, and the more severe form of upper and lower respiratory tracts injuries. The most notorious result as pulmonary edema from tear gases (CS) has been recognized by the British Government since 1971.2

CS is a white crystalline substance mixed with a pyrotechnic compound in a grenade or canister, it is a commonly use agent for riot control in Thailand. Smoke or fog of suspended particles in the form of aerosols, is extremely severe skin and mucous membrane irritant and lacrimator, especially in hot and humid weathers. Micronized form mixed with an antiglomerant (CS1) or treated with a silicone water repellant (CS2), can remain active for days to weeks when dusted on ground. Volunteers in military studies demonstrated the rapid recovery within minutes after removal from exposure, but overuse of the officers and rage among protestors can lead to prolonged and profound exposure, instead of transient aversion. Inhalation

Toxicology studies of high CS levels revealed an ability to cause chemical pneumonitis and fatal pulmonary edema. An estimation of respiratory concentration of CS at the center after detonated was 2,000-5,000 mg/m3, but if detonated in clusters or enclosed space, it may reach lethal level of 25,000-150,000 mg/m3. According to the U.S. Environmental Protection Agency (EPA), acute exposure guideline level 3 or lethal threshold for tear gases (CS) in human was 140 mg/m3 for 10 minutes.3 GI irritation may result in severe mucositis and gastroenteritis with a potential for perforation, skin sensitization with contact dermatitis was also observed.4,5

The issue of potential for increase blood cyanide levels of metabolized CS was controversy, resulted from underestimation the deglutinated oropharyngeal secretions and uncertain exposure time.6

In Thailand, inadvertent use of tear gas by the law-enforcement agency, and unawareness of its toxicity in the medical community, led to an extensive loss of health and human resources during the political turmoil in November and December 2013. This study aims to collect the clinical evidence of victims exposed to tear gases especially the adverse respiratory health.

Methods

The medical record of persons recovered from a mass demonstration, and receiving medical evaluation for injury from tear gases exposure in Siriraj Hospital during December 2013 and January 2014 were reviewed for immediate respiratory health effects. A mobile health station for interviewing and performing physical examination for the other victims, were also set up at Medical Service Unit near by the demonstration site at Democracy Monument, Rajdamnern Avenue, Bangkok, in January 2014. Spirometry and methacholine challenge testing according to American Thoracic Society standard were also performed in those without contraindications. Informed consent using respiratory health disaster format was performed.
Results

There were 2 patients among the total of 11 patients who developed acute adverse respiratory health effects. The first case was a previously healthy 65-year-old man. He developed chemical pneumonitis 7 days after multiple exposures. Chest radiograph revealed alveolar opacities at left lower lobe (Figure 1). CT scan 23 days after exposure demonstrated multifocal peripheral consolidations especially in the basal segments of left lower lobe (Figure 2) which became a pneumatocele in a follow-up CT scan at 38 days after exposure (Figure 3). Complete resolution was achieved at 138 days after an incident (Figure 4). The second case was a 43-year-old woman with a history of mild allergic rhinitis. She developed persistent cough after 14 days of massive and prolonged exposure. Her chest radiograph showed peribronchial thickenings in the mid right and left lung zones. CT scan demonstrated localized ground glass opacities and centrilobular nodules corresponded to bronchiolitis and alveolitis (Figure 5). Residual productive cough was persisted in the last follow-up visit at 4 weeks after an incident.

Figure 1. Alveolar opacities at left lower lobe of the first patient 7 days after an intense exposure to tear gases

Figure 2. Multifocal peripheral consolidations in the basal segments of left lower lobe of the first patient CT scan 23 days after exposure

Figure 3. A pneumatocele replaced area of consolidation at 38 days after exposure

Figure 4. A pneumatocele replaced area of consolidation at 38 days after exposure
At the medical unit nearby demonstration site, there were 35 victims voluntary participated in the study. There demographics and medical backgrounds are shown in Table 1. All of them had twice exposures to high concentration of tear gases, the first one at 33 days and the second one at 9 days before the assessment with the mean exposure time of 7.7 hours. Respiratory symptoms and signs are shown in Table 2. Abnormal spirometry was encountered in 8 victims (Table 3). Unfortunately, none of them could have a follow-up visit after the crisis was calm down.

Table 1. Demographic data and medical background of 35 victims exposed to high concentration of tear gases

<table>
<thead>
<tr>
<th>Character</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>47</td>
</tr>
<tr>
<td>Male:Female</td>
<td>26:9</td>
</tr>
<tr>
<td>Preexisting obvious respiratory disease</td>
<td>None</td>
</tr>
<tr>
<td>Atopic histor</td>
<td>4</td>
</tr>
<tr>
<td>Active smoker</td>
<td>18</td>
</tr>
<tr>
<td>Occupational exposure to fume or smoke</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2. Symptoms and signs of 35 victims

<table>
<thead>
<tr>
<th>Character</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasopharyngeal irritation</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Cough</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Sputum production</td>
<td>34 (97)</td>
</tr>
<tr>
<td>Immediate shortness of breath after exposure</td>
<td>20 (57)</td>
</tr>
<tr>
<td>Immediate wheezy after exposure</td>
<td>13 (37)</td>
</tr>
<tr>
<td>Nasopharyngeal inflammation</td>
<td>29 (83)</td>
</tr>
<tr>
<td>Oral mucosa hyperpigmented patch and hand dermatitis</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Adventitious breath sounds</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3. Spirometric results of 35 victims

<table>
<thead>
<tr>
<th>Character</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstructive ventilator defect</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Small airway obstruction</td>
<td>5 (14)</td>
</tr>
<tr>
<td>Airway hyperresponsiveness*</td>
<td>1 (3)</td>
</tr>
</tbody>
</table>

*This patient also had obstructive ventilatory defect

Discussion

Respiratory system toxicity of CS has not been adequately studied because of many confounding factors. Symptoms of chronic cough and shortness of breath were well recognized in those with high concentration exposure. Persons with asthma or COPD may be vulnerable to develop exacerbation at a low concentration exposure. A series of 18 patients from Egypt with heavy exposure to tear gases at the mean of 2.8 minutes was reported in 2011. All of them experienced nausea, severe coughing, and shortness of breath within 2 hours after exposure. On examination all patients exhibited flush face, skin erythema, and hoarsness. Severe wheezes and coarse crackles were identified in 16 of them, and one also established stridor. Chest radiographs were within normal limit, except for
increased bronchovascular markings in 3 patients. One patient was suspected to have reactive airway disease, but loss to follow-up.

The Turkish Medical Association published a report of at least 3 deaths following tear gases in 2007 and 2011, 1 from cardiac arrest, the other from pulmonary edema, and the last due to intracranial haemorrhage. In an investigation by the Turkish Thoracic Society for long term consequence of CS on the respiratory system, 93 males has had repeatedly exposed to tear gases for 2 years. Resting dyspnea was experienced in 44%, chest tightness 38%, and dyspnea on exertion 43%. Morning cough was presented in 32%, morning phlegm 28%, daytime cough 39%, daytime phlegm 42%, and phlegm for 3 months in 26%. Exposure to tear gases increased the risk of chest tightness, dyspnea on exertion, morning cough, and phlegm 1.9 to 2.4-fold. The mean maximal mid expiratory flow rate (MMFR) was 4,084.6±1,235.1 mL, which was significantly lower than that of controls (4,565.9±1,096.4 mL). There was a negative correlation between MMFR and total gas exposure.

At tissue level, a chemical reaction of CS ensues and forms malononitrile that transforms further to thiocyanate. This can create cyanide ions, which are responsible for cellular toxicity. Laminin is known to function in adhesion, contact, migration, and signal transmission of materials within tissue, especially alveolar basement membrane. In the rat model of CS exposure for 20 minutes daily in 3 consecutive days, the rapid decrease in laminin expression appeared as early as 12 hours and led to the disappearance of laminin within 3 days along with intense alveolar inflammation. After the process of inflammation disappeared in 7 days, reappearance of laminin occurred. Permanent damage of lung tissue due to laminin interference during regenerating process may be possible if prolonged and profound exposure to CS happen.

CS can also alkylate sulfhydryl groups which are potentially genotoxic. Some researchers have shown CS to be mutagenic in mice, but others have reported negative results. An experiment in mice and rats revealed more pulmonary tumors after 4-week inhalation exposure, although there was no statistical significant. Due to its effect in suppressing nonspecific esterase activity in mouse skin sebaceous gland, CS has potential use as a screening test for carcinogenic potential of suspected chemical agents.

Although this preliminary investigation has some limitations due to small number of subjects and no follow-up data, the acute and late notorious respiratory health effects of tear gases were demonstrated and emphasize this health hazard from a systematic review. It is the responsibility of the medical community to collect objective evidence of tear gases toxicity among the victims, and handle to those in charge of public safety. Future controlling measures of tear gases use in Thailand, or even alternatives rather than tear gases, should be seriously considered as a practice standard in civilized countries.

Conclusion

High concentration and prolonged exposure to tear gases could result in immediate disorders and late sequelae of the human respiratory system.

Acknowledgement

The expense for further investigation and treatment of some patients in this study was supported by Mrs. Kingtong Baiyoke.
References

สาขาวิชาโรคระบบการหายใจและวัณโรค ภาควิชาอายุรศาสตร์ คณะแพทยศาสตร์ศรีราชพยาบาล มหาวิทยาลัยมหิดล.

ที่มาและวัตถุประสงค์:
แก๊สน้ำตาที่ถูกใช้อย่างแพร่หลายในการควบคุมฝูงชนสามารถทำให้การทำงานของอวัยวะในหลายระบบมีผลลบ และ วางเกิดการทุพพลภาพขึ้นได้ การศึกษานี้เป็นการรวบรวมหลักฐานบางส่วนของพิษต่อระบบการหายใจจากการใช้แก๊สน้ำตาโดยไม่คำคิด ทำให้เป็นผลในระยะสั้นและระยะยาว.

วิธีการ:
ได้ทำการทบทวนเวชระเบียนผู้ป่วยที่บาดเจ็บจากการสัมผัสแก๊สน้ำตาระหว่างเหตุการณ์ความไม่สงบทางการเมืองในปี พ.ศ. 2556-2557 และได้รวบรวมข้อมูลการตรวจทางคลินิกและทางห้องปฏิบัติการสำหรับผู้ประสบภัยรายอื่นที่มารับการตรวจที่หน่วยบริการสุขภาพใกล้สถานที่ชุมนุม.

ผลการศึกษา:
รวบรวมผู้ประสบภัยได้ทั้งหมด 37 คน ไม่มีรายใดมีโรคระบบการหายใจอยู่ก่อนประสบภัย มี 4 คนมีภาวะภูมิแพ้อยู่ก่อน และ 18 คนที่ยังสูบทุจรึ่ยอยู่ ค่าเฉลี่ยของระยะเวลาการสัมผัสแก๊สน้ำตาคือ 7.7 ชั่วโมง พบผู้ป่วย 2 รายเกิดหลอดลมอักเสบและปอดอักเสบจากสารเคมี ในจำนวนผู้ประสบภัยอีก 35 จากที่มารับการตรวจที่หน่วยสุขภาพ เกือบทั้งหมดมีอาการไอและมีเสมหะเรื้อรังหลังการสัมผัส ตรวจพบการอักเสบในจมูกและคอของ 29 คน (ร้อยละ 83) พบความผิดปกติจากการตรวจสปีโรเมตรีได้ 8 คน (ร้อยละ 23) โดย 3 คนมีลักษณะของ obstructive ventilatory defect อีก 5 คนมีลักษณะของ small airway obstruction มีเพียง 1 คนที่ตรวจพบภาวะ airway hyperresponsiveness โดยที่พบ obstructive ventilatory defect ร่วมด้วย