Respiratory Health Effect of Persons Accidentally Expose to High Concentration of Chlorine Gas

Nitipatana Chierakul MD*,
Nuttapol Rittayamai MD*, Prachya Passaranon MD*,
Charttiwut Chamchod MD**, Bralee Suntiwuth MD***

** Division of Respiratory Disease and Tuberculosis, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand*
*** Department of Occupational Health, Bangkok, Thailand*
**** Department of Medicine, Rayong Hospital, Rayong, Thailand*

Objective: *To evaluate the short term and long term respiratory health effects of subjects who accidentally exposed to high concentration of chlorine gas.*
Material and Method: *There was an accidental leakage of sodium hypochlorite from an industrial factory in Rayong province in June 2010. Medical records of those who developed severe symptoms after exposed to high concentration of chlorine gas were reviewed. Prospective observational study was conducted after hospital discharge by interviewing with respiratory health questionnaires, physical examination, spirometry, methacholine challenge test, and home peak expiratory flow (PEF) monitoring at 2, 5 and 8 months after the event.*
Results: *Among 1,434 persons exposed to chlorine gas, 92 developed severe symptoms required hospital admission and 21 participated in the follow-up study at 2 months there after. Respiratory symptoms were noted in 18 participants. Three most common symptoms were dyspnea (81%), chest tightness (71%), and cough (67%). Obstructive defect from spirometry was identified in 2 participants, one of which also had bronchial hyper responsiveness (BHR) compatible with reactive airway dysfunction syndrome (RADS). Seven participants had abnormal PEF variability. There were 10 and 5 participants left in the follow-up visit at 5 and 8 months respectively. Two participants had persistent obstructive defect with additional two subjects were noticed. Those who had BHR and abnormal PEF variability remained unchanged.*
Conclusion: *Acute exposure to high concentration of chlorine gas causes both significant short and long term respiratory health effects. Most of the patients although have gradual improvement of respiratory symptoms, but some symptoms remain persistent. Few patients have lung function impairment lasting for at least 8 months.*

Keywords: *Chlorine, Respiratory symptoms, Spirometry, Bronchial hyperresponsiveness, Peak expiratory flow variability, Lung function impairment*

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Chlorine is a yellowish irritant gas with strong odor. Many chemical compounds that have been used widely for household and industrial purposes can emit chlorine. Human exposure usually results from accidentally leakage during transportation or storage. High concentration of chlorine gas exposure with various acute respiratory health hazards have been mentioned [1-4]. These acute effects of chlorine toxicity include cough, bronchoconstriction, respiratory distress, and even respiratory failure. Earlier study reported transient lung function impairment[5]. Later studies, however with long term follow-up period, revealed permanent deficit[6-10].

This prospective observational study aims to evaluate the respiratory health effect of high concentration chlorine gas exposure after accidental leakage from an industrial factory to the surrounding environment.

Material and Method

In June 2010, there was an accidental leakage of sodium hypochlorite from an industrial factory in Rayong province resulting in 1,434 victims of chlorine gas exposure. Medical records of those who required hospital admission were reviewed. Respiratory health assessment in the participants was performed using questionnaire interviewing along with physical

Correspondence to:
Chierakul N, Division of Respiratory Disease and Tuberculosis, Department of Medicine, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 0-2419-7757, Fax 0-2419-7758
E-mail: nitipat7@gmail.com

examination. Spirometry and methacholine challenge test were also performed using standardized protocol[11,12]. Home peak expiratory flow (PEF) variability according to the recommendation was monitored during the follow-up period[13]. Respiratory medications include bronchodilators and inhaled corticosteroid prescribed by physicians in charge was not restricted. Obstructive ventilatory defect is defined using lower limit of normal for Thais[14,15]. Diurnal variation of PEF more than 20% is considered abnormal as has been described[16]. Descriptive statistics are presented in percentage and mean with standard deviation. The study protocol was approved by the Siriraj Institutional Review Board.

Results

There were 92 subjects who required in-patient treatment. Two patients developed respiratory failure from acute respiratory distress syndrome and severe bronchospasm respectively: both survived. After the hospital discharge, 21 subjects participated in the initial respiratory health assessment at 2 months following the incidence. Thirteen subjects were female and 8 were male, the median age was 35 years (range 20-63). Smoking history was established in 10 subjects, but only one subject had significant consumption (> 10 pack-years). Only one subject has had atopic history before the exposure, with occasional use of oral antihistamine. All the subjects has never previously been exposed to high concentration of chlorine or other noxious gases. During the follow-up visit at 5 and 8 months, only 10 and 5 subjects were left for the evaluation. The main result for drop-out was shortage of income.

In the first assessment at 2 months, 18 out of 21 subjects (86%) had persistent respiratory symptoms, mostly were dyspnea, chest tightness, and cough (Table 1). The onset of respiratory symptoms ranged from 1-14 days. At the second visit of 5 months, 9 out of 10 subjects still had the symptoms, although they had decreased in severity. One subject remained symptomatic at the third visit of 8 months, two were in the recovery phase, and two had no residual changes. Spirometry could be performed in 20 subjects at the first visit, obstructive ventilatory defect was identified in 2 subjects, one of them also had bronchial hyperresponsiveness (BHR). This one patient, who developed respiratory symptoms within 24 hours after exposure, had obstructive ventilatory defect with BHR which fulfilled the diagnosis of reactive airway dysfunction syndrome (RADS)[17]. Four-week home PEF recordings were completed in 18 subjects; 7 had abnormal diurnal variation. One patient, who was a current smoker, had persistent abnormal PEF abnormality and markedly decrease of forced expiratory volume in the first second (FEV1) over the follow-up period. The details of spirometric parameters and follow-up data are shown in Table 2.

Discussion

Chlorine gas has an intermediate solubility which leads to its potential to irritate both upper and lower airways after high concentration exposure[18]. This is the first study in Thailand to demonstrate the acute and late respiratory health effects of exposure to high concentration of chlorine gas. Most of the subjects developed both upper and lower airways symptoms that may last long (for at least 8 months) before the recovery. Some of them had lung function deficit, but some developed severe symptoms without pulmonary function impairment.

The finding of persistent obstructive ventilatory defect without prior airway diseases in this study until 8 months after an exposure, resembled the

Table 1. Percentage of subjects with respiratory symptoms during 3 follow-up visits

Respiratory symptoms	Percentage		
	1st (2 months) n = 21	2nd (5 months) n = 10	3rd (8 months) n = 5
Dyspnea	81	80	20
Chest tightness	71	10	20
Cough	67	60	20
Stiff or runny nose	62	50	40
Sputum production	48	50	40
Wheezing	33	40	20

Table 2. Pulmonary function test results

Parameter	1st (2 months) n = 20	2nd (5 months) n = 10	3rd (8 months) n = 5
FEV1 % predicted (mean ± SD)	100 ± 16	97.9 ± 15	92.3 ± 24
FVC % predicted (mean ± SD)	101 ± 16	103 ± 15	96.1 ± 23
FEV1/FVC % predicted (mean ± SD)	96.2 ± 6.2	92.5 ± 5.8	93.7 ± 7.1
No. with obstructive ventilatory defect	2	4	2
No. with BHR	1*	0	1
No. with abnormal PEF variability (total)	7 (18)	2 (8)	#1 (2)

FEV1 = forced expiratory volume in the first second, FVC = forced vital capacity, BHR = bronchial hyperresponsiveness, PEF = peak expiratory flow, *PC_{20} = 5.6 mg/mL, #PC_{20} = 7.6 mg/mL

long-term results demonstrated in previous studies with the follow-up period from 2 to 12 years[7,9]. Lemiere et al, reported the near complete recovery of airway mucosal pathology and disappearance of BHR at 5 months post accidental injury[19]. This contrary effect may result from the confounding factors include concomitant exposure to other noxious gases, smoking status, and the effect of anti-inflammatory agents treatment.

Integration of home PEF monitoring in the present study demonstrates the potential and feasibility of this tool for monitoring the respiratory health of targeted subjects in the community. However potential limitation of the present study should be mentioned. Firstly, the baseline respiratory health questionnaire assessment was performed at 2 months after the incidence, so the recall bias was inevitable. Second, the number of participants was small, and nearly half of them were drop out in the subsequent follow-up visits. And lastly, the preexisting occupational lung disease could not be excluded in some participants with continuous exposure in their workplace before the incidence. However, lesson learnt from the present study should warrant the government agency, the community, and the factory owner, to set an effective plan for encounter this catastrophic event in the future.

Conclusion

Accidental exposure to high concentration of chlorine gas can lead to acute severe and chronic persistent respiratory health impairments. Preventive measures to reduce the chance of chemical leakage and appropriate control measures after the incidence should be reinforced.

Potential conflicts of interest

None.

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ผลกระทบต่อสุขภาวะระบบการหายใจของผู้ที่สัมผัสก๊าซคลอรีนความเข้มข้นสูงจากอุบัติเหตุ

นิธิพัฒน์ เจียรกุล, ปรัชญา ภัสสรานนท์, นัฐพล ฤทธิ์ทยมัย, ชาติวุฒิ จำจด, บราลี สันติวุฒน์

วัตถุประสงค์: เพื่อประเมินผลกระทบในระยะสั้นและระยะยาวต่อสุขภาวะระบบการหายใจของผู้ที่สัมผัสก๊าซคลอรีนความเข้มข้นสูงซึ่งรั่วไหลจากอุบัติเหตุ

วัสดุและวิธีการ: ในเดือนมิถุนายน พ.ศ. 2553 เกิดอุบัติเหตุมีการรั่วไหลของสารโซเดียมไฮโปคลอไรท์จากโรงงานอุตสาหกรรมในจังหวัดระยอง ได้ทำการติดตามผู้ป่วยที่มีอาการรุนแรงภายหลังสัมผัสก๊าซคลอรีนความเข้มข้นสูง โดยใช้การสัมภาษณ์ด้วยแบบสอบถามสุขภาวะระบบการหายใจ การตรวจร่างกาย การตรวจสไปโรเมตรีย์ การทำ methacholine challenge test และ การวัด peak expiratory flow (PEF) variability ที่บ้าน ณ เวลา 2, 5 และ 8 เดือนหลังเกิดเหตุการณ์

ผลการศึกษา: จากผู้สัมผัสก๊าซคลอรีนทั้งหมด 1,434 คน มีผู้ป่วยที่มีอาการรุนแรงทั้งหมด 92 คน เข้ารับการรักษาในโรงพยาบาล ในจำนวนนี้ 21 คน ได้เข้าร่วมการศึกษาในเดือนที่ 2 หลังเกิดอุบัติเหตุ โดยพบมีอาการในระบบการหายใจหลงเหลืออยู่ 18 คน (ร้อยละ 86) ที่พบบ่อยคือ เหนื่อย (ร้อยละ 81) แน่นหน้าอก (ร้อยละ 71) และ ไอ (ร้อยละ 67) จากการตรวจสไปโรเมตรีย์พบความผิดปกติแบบ obstruction 2 คนโดยพบ bronchial hyperresponsiveness (BHR) ร่วมด้วย 1 คนเข้าได้กับการวินิจฉัย reactive airway dysfunction syndrome (RADS) ในการติดตาม PEF variability ที่บ้านพบมีความผิดปกติ 7 คน เมื่อตรวจติดตามที่เดือนที่ 5 และ 8 หลังเกิดเหตุการณ์ มีผู้เข้าร่วม 10 คนและ 5 คนตามลำดับ ส่วนใหญ่อาการในระบบหายใจยังคงมีอยู่ในเดือนที่ 5 แต่ดีขึ้นในเดือนที่ 8 ตรวจพบผู้ที่มี obstruction คงเดิม 2 คนและมีเพิ่มขึ้นใหม่อีก 2 คน ผู้ที่มี BHR และมี PEF variability ผิดปกติ ยังคงไม่มีการเปลี่ยนแปลง

สรุป: การสัมผัสก๊าซคลอรีนความเข้มข้นสูงทำให้เกิดความผิดปกติต่อระบบการหายใจอย่างรุนแรงและเรื้อรัง ผู้ป่วยส่วนใหญ่แม้อาการจะค่อยๆ ดีขึ้นแต่ก็ใช้เวลาหลายเดือนและบางรายไม่หายสนิท ผู้ป่วยบางส่วนมีผลสมรรถภาพปอดผิดปกติซึ่งไม่ดีขึ้นแม้ติดตามเป็นระยะเวลานาน 8 เดือน