Confidence test for personal protective equipment

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After the sarin attack in Tokyo Subway in 1995 and terrorist attack in World Trade Center of New York City in 2001, many countries are alerted by the risk of terrorist attack. International experiences show that many victims would arrive at hospital by their own transport. Staff safety is an important issue to be addressed. This study is to determine the skin and respiratory protection of a model of level C personal protective equipment which is currently available in Hong Kong. (*Hong Kong j.emerg.med.* 2002;9:195-200)

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Introduction

After the sarin attack in Tokyo Subway[1] in 1995 and terrorist attack in World Trade Center of New York City[2] in 2001, many countries are alerted by the risk of terrorist attack. The contingency plan for Hazmat incidents is re-visited. Staff safety is an important issue to be addressed. There are four levels of personal protection for dealing with hazardous substances. They are described as level A through level D personal protective equipment (PPE), a combination with different types of chemical resistant clothing and respiratory protection.[3] International experiences showed that many victims would arrive at hospital by their own transport.[4] The emergency medical system (EMS) was bypassed and these victims might be contaminated. If the victims could arrive hospital alive, logically the concentration of the hazardous material should not be high. In many occasions, hospital decontamination team might operate in level C protection.[5] Therefore level C PPE was adopted by Hong Kong Hospital Authority (HA) for the protection of the hospital decontamination team. (Figure 1)

There are several models of level C PPE available in Hong Kong. The standard level C PPE adopted by Hospital Authority for hospital decontamination team includes the following: A chemical protective suit with hood (Kappler Model CPF2 2T426), inner surgical latex gloves and outer chemical resistant nitrile gloves (Ansell Model 37-175), chemical resistant knee level boot with steel toe protection (Sermi Model 904), a full-face mask (3M Model 6800 series) and multi-vapour canister-equipped respirator (3M Model 6006). The detail specifications of this PPE are shown in Figures 2a and 2b. The objective of this confidence test is to verify the skin and respiratory protection of this model of PPE (CPF2 PPE).

Figure 1. Level C PPE adopted by Hospital Authority.

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Protective clothing

- Tear resistance and chemical hold-out by laminating co-extruded barrier film to 1.5 oz. Polypropylene substrate
- In accordance with ASTM F1001 Chemical Test Battery on material (Breakthrough times of chemicals and gases), chemical resistant test
- Mullen Burst test (psi/kPa): 100/689
- Typical Physical Properties (measured per ASTM D751)
  - ✧ Breaking strength (Grab Tensile lb/N) MD (Machine Direction) : 65/289; XD (Cross Direction) : 43/191
  - ✧ Trapezoidal Tear (lb/N) MD (Machine Direction) : 29/129; XD (Cross Direction) : 19/84
- Breakthrough times normalized to a permeation rate of 0.1 ug/cm^2/min. in accordance with ASTM F739
- Coverall style with zipper front, attached hood, sock boot with boot flap, elastic wrist.
- Strapped seam closures
- Protect against liquid splash, vapors and particulates
- Temperature service range (In accordance with ASTM D751-Test Method for Coated Fabrics)
  - ✧ High temperature: 200°F (93°C)
  - ✧ Low temperature: 85°F (65°C)
- Limited-use multi-layer film material.
- Colour code: Grey colour
- Size range: XS-4X

Protective footwear

- PVC sleeve knee boot
- Steel toe-cap
- Steel mid-sole
- CE marked
- EN345 safety standard
- Yellow in colour
- Size range: 37 to 46

Figure 2a. Specifications of personal protective equipment (1).

Methodology

Four healthy men were randomly selected for this test. The inclusion criteria included good past health with no significant allergic history especially to tear gas (CS) and smoke. Those who had recent illness including flu, wearing glasses and without consent were excluded. All candidates would dress in CPF2 PPE and entered into a smoke chamber for 30 minutes. There should be minimal activities during the test so as not to affect the vital signs of these candidates. The first two candidates would be subjected to smoke challenge whereas the other two would be subjected to tear gas (CS) challenge. Positive and negative pressure seal check for full-face mask was performed before entering into the smoke chamber. The vital signs of these candidates was charted before and after the gas challenge. Environmental data at the time of test would also be captured. Each candidate was expected to stay in the smoke chamber for 30 minutes. However, those who could not tolerate the gas challenge during the test could come out of the smoke chamber at anytime.

The smoke chamber was a 5 x 5 x 3 m^3 concrete house. (Figure 3) This chamber was specially designed for training of personnel for the use of air-purifying respirator (APR). One smoke grenade (Model Gren Hand SMK SCR N126) was used for smoke test. This agent would cause mild irritation to respiratory tract

Protective glove

- Made of Nitrile compound
- Flocklined
- Thickness: 0.38 mm
- Length: 33 cm
- Slip on style
- High resistance to snags and punctures
- High resistance to most common chemicals
- Green in colour
- Size range: 6 to 11

Respirator:

- Materials
  - Faceseal - Silicone rubber
  - Nosecup - Thermal plastic rubber
  - Head harness - Thermal plastic rubber
  - Lens - Polycarbonate
  - Buckles - Plastic
  - Particulate filter - Polypropylene
  - Multi-gas & vapour filter - Treated activated carbon
- Filter performance
  - NIOSH/DHSS: TC-84A-0689
  - Meet requirement of NIOSH certification test for N-series class, 95% filter efficiency level respirator from 42 CFR Part 84 Sec 84.181
  - At least 95% filtration efficiency against 0.3 micron aerodynamic mass median diameter aerosol of sodium chloride, filter performance will be greater against larger and smaller sized non-oil based particles
  - Tested to a specified maximum loading of 200 mg of sodium chloride
  - Meet requirement of NIOSH certification test for gas and vapour cartridge from 42 CFR Part 84 Sec 84.207
  - Service life against different gases and vapour at approximately 25°C and 50±5% relative humidity.

Figure 2b. Specifications of personal protective equipment (2).

Figure 3. Smoke chamber for confidence test.

but there was no irritation to skin. Five CS bullets (Model Ferret SGA-100) were used for CS test. This agent would cause irritation to both respiratory tract and skin. CPF2 PPE was first subjected to respiratory protection challenge (smoke test) and then followed by respiratory and skin protection challenge (CS test). The pictures of smoke grenade and CS bullets were shown in Figure 4.

Results

Environmental data

On the test day, the weather was cloudy with ultraviolet index 2.2 (low). The temperature were

Figure 4. Diagrams of CS bullets and Smoke grenade.

17°C for out-door and 21°C for inside smoke chamber respectively. The relative humidity was 86%. The wind speed was 20-30 km per hour (moderate) and the size of the chamber was 5 x 5 x 3 meter.[3] (Table 1)

The mean age of the candidates was 38.5 year. Their average height and weight were 170 cm and 60.5 kg respectively. All of them had good past health and there was no history of allergy especially to CS and smoke. The first 2 candidates could tolerate smoke test for 3 minutes 55 seconds and 11 minutes and 22 seconds respectively whereas the last 2 candidates could tolerate CS test for 6 minutes 10 seconds and 5 minutes 36 seconds respectively. All of them were in good condition and were fully conscious after the test. Their vital signs were essentially the same before and after test. (Table 2)

No candidates experienced skin irritation in CS test. All candidates experienced cough and throat discomfort after smoke and CS tests. All candidates in CS test group experienced mild irritation to their eyes as well. In smoke test group, all candidates claimed that they were well protected. However, there was leakage after using their walkie talkie to talk continuously for about 2 minute. In the CS test group, all candidates claimed that initially they could tolerate the CS challenge well. However, after about 5 minutes, they started to experience throat irritation and choking together with mild irritation to their eyes.

Discussion

The main effects of this riot-control agent are pain, burning, and irritation of exposed mucous membranes and skin. This is a good agent to test the safety of PPE. Eye contact with this agent produces a sensation of conjunctival and corneal burning and leads to tearing, blepharospasm, and conjunctival injection. Contact with the delicate mucous membranes of the nose produces a burning sensation, rhinorrhoea, and sneezing; a similar burning sensation accompanied by increased salivation occurs after contact with the mouth. Inhalation causes burning and irritation of the airways with bronchorrhoea, coughing, and a perception of a "tight chest" or an inability to breathe. Contact with skin causes a tingling or burning sensation and may cause erythema. The erythema begins several minutes after exposure and generally subsides 45-60 minutes after termination of exposure. Under conditions of high temperature, high humidity, and high concentration of agent there may be more severe dermatitis starting with erythema hours after exposure and followed by vesication. A transient increase in heart rate and blood pressure occur in people immediately on exposure to a riot-control agent or immediately after onset of exposure. The biological

Table 1. Environmental data

Date & Time:14:30 hours, 25 Jan 2002	Outdoor*	Inside smoke chamber
Weather	Cloudy, UV index 2.2	---
Temperature	17°C	21°C
Humidity	86%	86%
Wind	20-30 km/hr	---
Size of chamber	---	5 x 5 x 3 m^3

UV index: Ultraviolet Index, 2.2 = low

* Source from Hong Kong Observatory

Table 2. Personal data and vital signs

Test subject	1		2		3		4	
PPE protection level	C		C		C		C	
Challenge agent	Smoke		Smoke		CS		CS	
Weight (kg)	58		60		64		60	
Age (year)	37		37		40		40	
Height (cm)	165		165		175		175	
Duration in chamber (min, sec)	3'55''		11'22''		6'10''		5'36''	
General condition	Good	Good	Good	Good	Good	Good	Good	Good
GCS	15	15	15	15	15	15	15	15
Dehydration	No	No	No	No	No	No	No	No
Eye irritation	No	No	No	No	No	Yes	No	Yes
Cough	No	Yes	No	Yes	No	Yes	No	Yes
Respiratory rate (per min)	16	24	18	20	14	18	16	18
Throat discomfort	No	Yes	No	Yes	No	Yes	No	Yes
Peak flow rate (L/min)	570	580	580	540	530	500	580	620
Skin irritation	No	No	No	No	No	No	No	No
SpO_2 (%)	98	99	99	98	97	98	98	98
Body temperature (°C)	35.8	36	36	36	36	36	36	36.1
Blood pressure (mmHg)	115/56	116/71	118/82	155/92	126/58	126/70	120/79	119/74
Pulse (per min)	77	78	68	86	72	84	83	87
Respiratory rate (per min)	16	24	18	20	14	18	16	18

GCS: Glasgow Coma Scale

effects from CS begin seconds after exposure and continue for 15 minutes or so after one leaving the contamination to fresh, clean air.

The concentration of smoke and CS in the test chamber was very high. All candidates did not experience skin irritation during the test. Thus the skin protection of this CPF2 PPE was good. However, the respiratory protection of this CPF2 PPE was limited. All candidates experienced throat discomfort and cough after gas challenge. In smoke test, the candidates claimed that initially the protection was very well. After they talked for a while, the insulating power of the mask deteriorated and gush of smoke was leaked into the mask. The movement of facial muscle during conversation might be the cause of this leakage. In CS test, the candidates claimed that initially the respiratory protection was good. However, after about 5 minutes, the CS gas started to penetrate the canister filter and they experienced throat discomfort and choking. Moreover, the insulating power of nose cup of the full-face mask was not strong so that traces of CS leaked into the face piece and cause mild irritation to eyes. (Figure 5) The canister

Figure 5. Possibility of leakage from respiratory chamber to facial chamber.

3M-6006 could absorb multiple types of industrial vapours and smoke. However, it could not filter chemical warfare agents and that is the reason why it could penetrate 3M-6006 filter.

Conclusion

Many victims of Hazmat incidents will go to hospital using their own transport and the EMS is bypassed. These victims may be hazardous to hospital staff and cause secondary contamination to hospital facilities. If these victims can arrive at hospital alive, the concentration of the hazardous materials should not be high and level C protection should be adequate to deal with these victims. The CPF2 PPE has good protection to skin even in the presence of very high concentration of CS. Therefore, the skin protection of CPF2 PPE is adequate for hospital setting. However, its protection to respiratory tract is limited. Therefore, staff dressed in CPF2 PPE should not work in hot or warm zones of the incident site, where the concentration of the hazardous material is high. Moreover, CPF2 PPE is not recommended for indoor activities for the same reason and therefore hospital decontamination should be done outdoor whenever possible. Furthermore, conversation may be a cause of leakage in CPF2 PPE so unnecessary conversation with decontamination team members should be kept to minimum.

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