An overview of chemical warfare agents

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Chemical warfare agent is defined as a chemical which is intended for use in military operations to kill, seriously injure, or incapacitate humans (or animals) through its toxicological effects. Chemical agents are relatively simple to make and easy to transport. Moreover, their effects are immediate and dramatic. Therefore chemical weapons are commonly used by terrorists to kill or injure in order to achieve certain political purposes. Although chemical incident is uncommon, however, once it occurs, the consequence will be great. Therefore, fundamental knowledge about the basic concepts, toxicity, personal protection, decontamination and treatment with respect to chemical incident are very important. (*Hong Kong j.emerg. med.* 2002;9:201-205)

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Introduction

There are many definitions for chemical warfare agents (CWA). *Webster Ninth New Collegiate Dictionary* defines the term chemical warfare as tactical warfare using incendiary mixtures, smokes, or irritant, burning, poisonous, or asphyxiating gases. A working definition of a chemical agent is a chemical which is intended for use in military operations to kill, seriously injure, or incapacitate humans (or animals) through its toxicological effects. The prevailing attitude of civilian healthcare providers was that chemical agents were used only on Afghans, Kurds, and in battle such as Iran-Iraq War in 1980s. It was not until the sarin attack in Tokyo Subway[1] on 8th March 1995 that attention was drawn to this issue. The horror of terrorist attack in Word Trade Center of New York City[2] on 11th September 2001 still exists. According to Secretary for Security of Security Bureau, Hong Kong was a relatively safe place. However, hoax attacks of anthrax still occurred in Hong Kong. Chemical agents are relatively simple to make and easy to transport. Moreover, their effects are immediate and dramatic. Therefore chemical weapons are commonly used by terrorists to kill or injure in order to achieve certain political purposes. In order to have a better control of potentially hazardous situations, treatment of casualties, and decontamination of victims, emergency personnel should prepare for the possibility of handling chemical hazards in their areas.[3]

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History

The Chinese used arsenical smokes as early as 1000 BC. Solon of Athens put hellebore roots in the drinking water of Kirrha in 600 BC. Allies of Sparta in the Peloponnesian War took an Athenian-held fort by directing smoke from lighted coals, sulfur, and pitch through a hollowed-out beam into the fort in 424 BC.[4] The first large-scale use of chemical agents was started in World War I. In 1915, the Germans released chlorine gas against the Allied positions at Ypres, Belgium, resulting in over 5,000 casualties.[5-7] Between World Wars I and II, many countries continued to develop their capability for chemical warfare, in spite of a ban by the Geneva Treaty in 1925.[8] In the late 1930s, a German industrial chemist, Dr. Gerhart Schrader, synthesized tabun (GA), an extremely toxic organophosphorus compound. Two years later, he synthesized sarin (GB), a similar but even more toxic compound. During World War II, Germany weaponized thousands of tons of these potent organophosphorus compounds that came to be called nerve agents.[9] In World War II Japan and German continued to use CWA as weapons. During the Yemen War in 1963, there was evidence that Egypt used mustard bombs in support of South Yemen against royalist troops in North Yemen.[10] The result of the investigation by the United Nations revealed that Iraq had used vesicant mustard and the nerve agent against Iran in 1980s.

Classification of CWA

Chemical agents are classified by either their physiological actions or their military use.[11]

Physiological classification

1. Lung-damaging agents (choking agents) include phosgene (CG), diphosgene (DP), chlorine (CL), and chloropicrin (PS). These agents damage the lungs and irritate eyes and respiratory tract. They also act on alveoli to produce acute pulmonary edema.
2. Blood agents (cyanogens) include hydrogen cyanide (AC) and cyanogen chloride (CK). These agents are transported by blood to all body tissues where the agent blocks the oxidative processes by binding to cytochrome a3 oxidase, preventing cells from utilizing oxygen, resulting in cellular anoxia. When the central nervous system is affected, respiration will stop and circulatory system will collapse.
3. Blister agents (vesicants) include sulfur mustard (H/HD) and nitrogen mustard (HN), lewisite (L), and phosgene oxime (CX). Blister agents produce irritation to eyes and skin, resulting in formation of blister. When inhale, it can damage the mucous membranes of the respiratory tract resulting in pseudomembrane formation.
4. Nerve agents (anticholinesterase) such as Tabun (GA), Sarin (GB), Soman (GD), GF, and V-agent (VX) inhibit the cholinesterase enzymes. The cholinesterase enzymes are responsible for the hydrolysis of acetylcholine, a chemical neurotransmitter. This inhibition creates an accumulation of acetylcholine at cholinergic synapse that leads to over-stimulation and transmission of nerve impulse.

Military classification

1. Toxic chemical agents which can cause serious injury or death. They include nerve agents, blister agents, lung-damaging agents, and blood agents.
2. Incapacitating agents which produce temporary physical or mental effects, or both.

Important concepts

Chemical agents can exist in solid, liquid or gaseous states, depending on temperature and pressure. However, some chemical agents such as riot control agents can be dispersed as aerosols, which is defined as a collection of tiny solid particles suspending in the air. Some chemical agents can exist in vapour form, which is defined as the gaseous form of a substance at a temperature lower than the boiling point of the substance at a given pressure. Some chemical agents are volatile (non-persistent) but some are persistent. The more volatile the substance, the easier it vapourises. The more persistent the substance, the longer it will stay on the object and decontamination is important to prevent further absorption into the body. The arbitrary but generally accepted division between persistent and non-persistent agents is 24 hours, meaning that a persistent agent will still constitute a liquid hazard and contaminate surfaces for 24 hours or longer. Examples of persistent agents are mustard and VX. Examples of non-persistent agents are GB and cyanide.

Toxicity of CWA

The toxicity of chemical agents is measured in special unit. For chemical agents that exist in liquid or solid states, the toxicity is measured as Effective Dosage (ED_{50}), meaning that the quantity of the agent will predictably cause effect in 50% of the given population. Incapacitating Dosage (ID_{50}) means the quantity of the agent will predictably cause incapacitation in 50% of the given population. Similarly, Lethal Dosage (LD_{50}) means the quantity of the agent will predictably cause death in 50% of the given population. For chemical agents that exist in gaseous, vapour or aerosol states, the toxicity is measured as a product of concentration-time, which refers to concentration (usually in mg/m^3) multiply by time (usually in minutes). ECt_{50} means that the quantity of the agent will predictably cause effect in 50% of the given population. ICt_{50} means that the quantity of the agent will predictably cause incapacitation in 50% of the given population. LCt_{50} means that the quantity of the agent will predictably cause death in 50% of the given population. The ascending order of toxicity of the four groups of CWA is: pulmonary agents, blood agents, blister agents and nerve agents.[12]

Protection

There are four levels of protection for dealing of hazardous substances. They are described as level A to level D chemical protective clothing in combination with different types of respiratory protection.[13] Level A protection should be worn when highest level of respiratory, skin, eye and mucous membrane protection is needed. It consists of a fully-encapsulated, vapour tight, chemical resistant suit together with self-contained breathing apparatus (SCBA). Level B protection should be selected when the highest level of respiratory protection is needed, but a lesser degree of skin and eye protection is required. It consists of chemical splash suit and SCBA. Level C protection should be selected when the types of airborne substance is known, concentration is measured, criteria for using air-purifying respirators are met and skin or eye exposures are unlikely. Level D protection is primarily a work uniform. It provides no respiratory protection and minimal skin protection. It should not be worn on any site where respiratory or skin hazard exist.

PPE complications

Personnel wearing PPE are likely to encounter a number of potential problems, including limited visibility, reduced dexterity, claustrophobia, restricted movement, insufficient air supply, dehydration and the effect of heat and cold. According to our local experience, 8 staff working in a local emergency department had tried level A and B PPE during Hazmat Medical Life Support workshop which was held in Singapore on 25th-26th September 2001. Only one of them could successfully perform intubation and intravenous access after donning of level A or B PPE. Moreover, in a Hazmat disaster drill dated on 27th April 2000, 6 staff in level C PPE working outdoor for 30 minutes experienced dehydration and heat exhaustion. On that day the environmental temperature was 28 degree Celsius and the relative humidity was 89%. The results of their vital signs were shown in Table 1. If the victims can arrive hospital alive, logically the concentration of the hazardous material should not be high. Donning of level A or B PPE required special training and it is not cost-effective to maintain these equipments. In many occasions, hospital decontamination team may operate in level C PPE.[14] Therefore Level C PPE was adopted by Hong Kong Hospital Authority (HA) for the protection of the hospital decontamination team.

Triage categories

It is important to note that in a terrorist attack, there will be a large number of victims. However, in fact only a minority of victims is truly injured by conventional weapons, hazardous (chemical, biological, nuclear) agents, or combination of both. The rest of the people who are in panic attack may experience symptoms which may resemble CWA attack. These may be due to their undue psychological or physiological response. Therefore, triage is very important to pick up the true victims and not to overload the emergency departments. Fundamental knowledge about CWA is important in the triage process. According to United States Army Medical Research of Chemical Defense, these victims can be classified into four categories:[15]

Table 1. Vitals signs of decontamination team members before and after Hazmat drill on 27th April 2001.

Decon. team	Member #1	Member #2	Member #3	Member #4	Member #5	Member #6
Time out	10:25	10:25	10:25	10:25	10:45	10:45
Temp	37°C	37.5°C	37°C	37°C	37.5°C	37°C
BP	171/88	120/80	161/93	125/87	137/80	131/70
Pulse	120	98	102	102	112	96
Time in	11:18	11:20	10:50	10:50	11:15	11:15
Temp	38.4°C	38.3°C	37.9°C	37.6°C	38.2°C	37.1°C
BP	157/86	141/73	150/47	150/60	141/73	171/82
Pulse	148	154	109	111	92	125

Decon. team : Hospital decontamination team
Temp : Body temperature
BP : Blood pressure
Time out : Time out for drill
Time in : Time in after drill
Environmental temperature on that day: 28°C
Relative humidity on that day: 89%

a. Immediate: Abnormal vital signs, require immediate intervention to save life.
b. Delayed: Care can be delayed but there is no change in outcome.
c. Minimal: Walking and talking victims with minor injury.
d. Expectant: Survival unlikely even with optimal treatment.

Decontamination

Majority of the very toxic chemical agents can penetrate skin. Therefore, decontamination should be done as soon as possible. Removing of clothing is the essential first step in the treatment of contaminated victim. Once the clothing has been removed, the victim will remove 80% of the contaminant after liquid contamination and nearly 100% after vapour contamination.[16] Removal of clothing is important because of the possibility of "trapped vapour". This may be the only decontamination procedure that is required for those victims exposed to a chemical gas, vapour or biologic exposure. Although some centers advocate 0.5% hypochlorite solution as universal decontamination agent,[17] however, it is generally accepted that copious amount of water and soap are equally effective for contamination reduction process as majority of the contaminants can be removed by physical means. All suspected victims are considered contaminated until proven otherwise. Decontamination team members should watch and ensure the decontamination process is thorough and adequate. Cyanide is volatile and is unlikely to remain in the wound, therefore it is safe to healthcare workers after decontamination. Mustard & Nerve agents will react with tissue rapidly and then biotransform (unlikely to survive if wound has large amount of nerve agent), therefore it is safe to surgeon after decontamination. However, foreign body in wound is an exception. It should be removed by no touch technique.

Treatment and antidotes

First aid treatment includes termination of exposure, basic life support for airway, breathing and circulation. Decontamination should be done as soon as possible as many CWA agents can penetrate skin quickly. Other supportive treatments include oxygen, fluid resuscitation, correction of acid-base balance, monitoring of cardiac arrhythmia and prevention of sepsis. There is no specific antidotes for pulmonary and blister agents. However, antidotes are available for blood and nerve agents. For cyanide poisoning, the combination of sodium nitrite and sodium thiosulfate is the best therapy. When the two substances are injected intravenously, one after the other, namely nitrite followed by thiosulfate, they are capable of detoxifying approximately 20 lethal doses of sodium cyanide and are effective even after respiration has stopped. As long as the heart is still beating, the chance of recovery by utilizing this method is very high. For nerve agent poisoning, combination of atropine and pralidoxime is an effective therapy. However, it should be noted that the usual dosage of atropine for nerve agent poisoning will be very high, and it should be titrated according to titration of the responses such as drying of secretion and improvement of airway resistance. Pralidoxime can dislodge nerve agent from the enzyme cholinesterase. However, some nerve agent such as soman will form tight covalent bonds with cholinesterase quickly, rendering pralidoxime ineffective. Pre-treatment with pyridostigmine against nerve agent may be used to decrease nerve agent toxicity but the benefit and risk must be checked before consideration of this drug.

Conclusion

The prevailing attitude of civilian healthcare providers was that chemical agents incidents are extremely rare. It was not until the sarin attack in Tokyo Subway in 1995 and terrorist attack in Word Trade Center of New York City in 2001 that attention was drawn to this issue. In Hong Kong, hoax attacks by anthrax still occurred since 17th October 2001. Chemical agents are relatively simple to make and easy to transport, and their effects are immediate and dramatic. Therefore chemical weapons are commonly used by terrorists to kill or injure in order to achieve certain political purposes. Although chemical incident is uncommon, however, once it occurs, the consequence will be great. Therefore, fundamental knowledge about the basic concepts, toxicity, personal protection, decontamination and treatment with respect to chemical incident are very important.

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