Review

Clinical review: Tokyo – protecting the health care worker during a chemical mass casualty event: an important issue of continuing relevance

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Abstract

Determine the effectiveness of decontamination, and perform thorough dry or wet decontamination, depending on the circumstances. Always remain cognizant of the fact that, even after decontamination has been completed, contamination may not have been completely eliminated. Perform periodic monitoring to determine whether secondary exposure has occurred in health care workers; if it appears that secondary exposure has occurred, then the PPE level must be increased and attempts must be made to identify and eliminate the source of the contamination. Finally, if the victims were exposed through ingestion, then consider the possibility that secondary exposure will occur during gastric lavage.

Introduction

In the Tokyo subway sarin attack in March 1995, many health care workers experienced secondary exposure [1]. Although the various organizations that responded to the incident were aware that the causative agent was a chemical substance, many cases of secondary exposure occurred because of lack of sufficient knowledge of the decontamination and protective measures that needed to be implemented. This article discusses aspects related to the secondary exposure that occurred in the 1995 subway incident in Tokyo, and reviews the measures that health care workers must implement to protect themselves in the event of a chemical mass casualty incident.

Secondary exposure in the Tokyo subway sarin attack

No primary decontamination was performed at the scene of the Tokyo subway sarin attack. In addition, the first responders and the health care workers involved in the initial response were not wearing personal protective equipment (PPE). As a result, 135 (9.9%) of the 1364 fire department personnel who responded to the incident experienced secondary exposure while transporting victims to emergency facilities [2]. Although the extent of secondary exposure among police department personnel has not been made public, it is thought to have been similar to that observed among fire department personnel. Fortunately, no lives were lost due to secondary exposure because the purity of the sarin used in the Tokyo subway attack was only approximately 30%. It is thought that the use of sarin of low concentration was because the group responsible for the attack – the Aum Shinrikyo cult – received information on a police investigation into their activities, which they intended to disrupt by launching the attack. The short time period between the planning and execution of the attack meant that the concentration of the sarin used was relatively low. In contrast, nearly pure sarin was used in the Matsumoto sarin attack [3,4] in 1994. If high-purity sarin had also been used in the Tokyo attack then lives might have been lost due to secondary exposure.

In the Tokyo subway attack secondary exposure also occurred at medical facilities [1,5]. As a result of its proximity to the subway station where many of the victims were exposed to the agent, St. Luke's International Hospital received 640 victims on the day of the incident. A survey conducted at St. Luke's after the incident found that 23% of the hospital staff experienced secondary exposure [1]. The

ICU = intensive care unit; PPE = personal protective equipment.

rates of secondary exposure by occupation were 39.3% in nursing assistants, 26.5% in nurses, 25.5% in volunteers, 21.8% in doctors and 18.2% in clerks. It is thus apparent that the extent of secondary exposure among individuals increased in proportion to the duration and degree of physical contact they had with victims.

The rate of secondary exposure at various locations was 45.8% in the hospital chapel, 38.7% in the intensive care unit (ICU), 32.4% in the outpatient department, 17.7% in the ward and 16.7% in the emergency department. The low number of individuals who experienced secondary exposure in the emergency department was attributed to the fact that the staff in this area were breathing outdoor air and the ventilation in the department was extraordinarily high, given that the automatic doors at the ambulance entrance were often open because of the continuous arrival of victims. Conversely, the high incidence of secondary exposure in the chapel was attributed to the fact that the air circulation in the chapel had never been good and because many victims were received there. The incident occurred during the winter, and the victims were received at the chapel wearing the same clothes that they had been wearing at the time of the attack. It is thus likely that whenever an overcoat was removed or a person was moved, sarin trapped in, or under, the person's clothing escaped, resulting in secondary exposure. Eventually, victims were asked to remove their clothing if possible, and it was stored in plastic bags. Although these measures could be implemented for most of the patients who were hospitalized, it could not always be done for those victims who went home after undergoing a series of standard outpatient test observations [1].

That 38.7% of personnel in the hospital ICU experienced secondary exposure at the time of the Tokyo attack is a shocking finding. Severely injured victims may be exposed to higher levels of the causative agent than victims who suffer mild injury, and those with severe injuries are naturally brought to the ICU. The likelihood that patients in the ICU will become contaminated with the causative agent is therefore greater. The likelihood of such an occurrence should be clearly recognized, and measures should be conceived to cope with such circumstances in the event that they occur. Intensivists, even more than emergency physicians, should always be mindful and prepared to implement mitigation measures to ensure their own safety in a chemical mass casualty event.

Mass decontamination

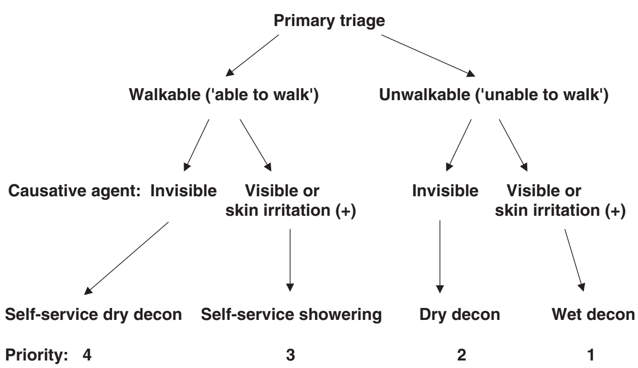
Based on the lessons learned from the Tokyo incident, the effectiveness of the emergency services and their response to such an incident can be improved by addressing issues related to the decontamination of victims and by donning PPE. Fire department personnel should cordon off the site of the incident in cooperation with the police, and should decontaminate victims because this is an essential and important prerequisite for protecting medical facilities from contamination. Irrespective of the skill of the emergency services or the spatial extent of the emergency itself, cordoning off the area and establishing a decontamination system at the site is likely to take at least 30 min. By this time, victims will begin to arrive at medical facilities in waves, either under their own power or assisted by the drivers of taxis or private cars who happened to be passing and offered help. The more severely injured the victims are, the greater the urgency will be to get them to medical facilities, but the more likely will it be that they are insufficiently decontaminated. This risk varies from country to country, and depends on factors as varied as the extent to which physicians are involved at the site of such emergencies and the range of medical care that paramedics are allowed to administer [6].

Consequently, decontamination at medical facilities is necessary, but the capacity to administer mass casualty chemical decontamination at medical facilities is inadequate throughout the world [7–10]. There is an urgent need to respond quickly after the onset of such incidents, even if the causative agent, its characteristics (whether it is a solid, liquid, gas, chemical splash, or aerosol) and its concentration are unknown. If the contamination can clearly be seen with the unaided eye or if irritation suggestive of a blistering agent is present at the sites of exposure, then decontamination with water (wet decontamination) should probably be performed. In other cases, the victims' clothing should be removed (dry decontamination) at least (Fig. 1). Each hospital must establish an area for victims to change their clothing, with replacement clothes prepared in advance. Ideally, a monitor should be used to confirm that the causative agent has been effectively removed by the decontamination process. However, chemical weapons monitors are expensive and they require skill to operate and maintain. Moreover, the addition of monitoring to the decontamination process risks reducing the efficiency of decontamination. Consequently, it is impractical for a medical facilities to purchase such equipment [11]. In Japan only a few university hospitals with advanced emergency medical centres have chemical monitors such as the ChemPro 100® (Environics, Mikkeli, Finland). If the facility is uncertain regarding whether all of the contaminants were removed in the decontamination process, and it appears that health care workers may be subjected to secondary exposure, then the possibility of incomplete decontamination must not be ruled out.

Personal protective equipment

The use of PPE is as important as decontamination itself. PPE is mainly used in the receiving and decontamination areas in hospital settings. Many reports in the literature have asserted that the use of level C protective equipment (ambient air is adsorbed and filtered using an absorbent cartridge to protect the respiratory tract) is adequate for medical facilities [6,11,12]. However, use of level C equipment is pointless if the causative agent is a gas that is not absorbed by the

Figure 1



Practical decontamination strategy. Adapted from the *Decontamination Manual* (the official report of the Task Force on the advanced procedures of fire righters by the Japanese National Fire Defense Agency, 2004).

cartridge; for instance, such devices may not be able to filter out carbon monoxide, or they may not be capable of the heavy metal doping of activated charcoal required to remove cyanides. Consequently, some investigators have expressed concern about the safety of using level C protective equipment, noting that the chemical weapons used by terrorists are not limited to known agents [11].

Therefore, there is currently no global consensus regarding the level of PPE that should be used at medical facilities [12–14]. Conversely, the filter cartridges that are used for civilian PPE applications were developed by the military to filter out all known agents of chemical warfare and major civil toxic hazards. In fact, military forces all over the world use level C protection; this is because the balloon-like level A suits with their air cylinders represent potential targets on the battlefield. Similarly, the US Occupational Safety and Health Administration recommends use of a powered air-purifying respirator (a form of level C PPE) in hospital settings.

Given that an attack on a society's weak points is by definition an act of terrorism, it is important to focus on those areas and develop worst case scenarios accordingly. Consequently, level C PPE is likely to be sufficient for most hospital settings (receiving and decontamination areas). However, if health care workers responding to an incident exhibit symptoms, then level B protective equipment, which provides a higher level of protection, should be used until the source of the contamination can be identified. Level B equipment either has an air cylinder or it has an air hose that enables fresh air to be obtained from an air supply. It is recommended that medical facilities use the air line type PPE, to which air is supplied through a hose, because the use and maintenance of air cylinder PPE requires training. Furthermore, nearly all medical facilities are already equipped with lines for compressed air, making it practical to use air line type PPE in hospitals.

There are two types of air line type PPE. In one type compressed air is blown continuously into the hood, whereas in the other compressed air is delivered by a mask with a regulator that supplies air on demand. Although the former type permits easier breathing and is safe, it consumes 140 l/min compressed air, placing a burden on the compressed air lines in the hospital. An excessive burden on the compressed air lines could adversely affect mechanical ventilators and other devices that also use the lines. The pressure demand type level B PPE is somewhat more expensive than the continuous supply air line type, and requires the user to be trained to fit the mask. However, it only consumes 40 l/min air and imposes lesser burden on the compressed air system as a whole.

Depending on the circumstances of the facility, either of these level B PPE types should be obtained and prepared for use. Notwithstanding, it is important to remember that level B PPE carries inherent dangers for the wearer. One potential disadvantage is that the time taken to put on the equipment can be considerable, and the system may become contaminated before staff are protected. Some hospitals have introduced level B PPE in Japan.

Secondary poisoning of medical personnel by a toxic gas was recently reported in Japan when toxic agents reacted with gastric acid during a gastric lavage procedure conducted in a patient who had ingested a toxic substance [15,16]. The episode raised awareness of the necessity for PPE, and closed gastric lavage kits are now commonly employed in Japan when gastric lavage is performed. When sodium azide, cyanides, sulfides and arsenious acid react with gastric acid, hydrogen azide, hydrogen cyanide, hydrogen sulfide and arsine, respectively, are produced. (Of these compounds, hydrogen azide, for example, cannot be absorbed by absorbent cartridges and is thus used to produce chemical weapons.) Although the term 'chemical terrorism' currently implies terrorism involving chemical weapons, it also has become necessary to guard against chemical terrorism involving the intentional contamination of food and drink with lethal chemical substances. For the terrorist, such methods are easier to execute than other means of disseminating a chemical agent. This underscores the need for precautions against secondary exposure during gastric lavage.

Protection of health care workers in the intensive care unit

It is necessary to confirm whether appropriate decontamination has been undertaken at the site of the incident or where the victims are received (such as the site of one of the services). As mentioned above, a monitor should ideally be used to confirm the extent of decontamination, but this is usually not practical and the efficacy of decontamination is thus not established in this manner. Consequently, rather than assuming that decontamination was complete, periodic monitoring should be performed to determine whether secondary exposure has occurred among health care workers. If it appears that secondary exposure has occurred, then the level of protection among emergency workers should be increased and the source of the contamination determined. In the event of a terrorist attack using chemicals, ICUs are likely to receive severely injured patients from emergency rooms in rapid succession, and appropriate precautions should be taken in such cases [17]. Expired air should be processed using a mechanical ventilation system [6]. However, unlike most operating theatres, ICUs often do not have ventilation systems that are designed to remove excess gas. Consequently, measures such as attaching a reservoir to the air outlet and emptying the reservoir by continuous suction should be implemented in the event of a chemical mass casualty event.

Conclusion

The following is a summary of the methods that can be employed to protect health care workers during a chemical mass casualty event. Determine the effectiveness of decontamination, and perform thorough dry or wet decontamination, depending on the circumstances. Always remain cognizant of the fact that, even after decontamination has been completed, contamination may not have been completely eliminated. Perform periodic monitoring to determine whether secondary exposure has occurred in health care workers; if it appears that secondary exposure has occurred, then the PPE level must be increased and attempts must be made to identify and eliminate the source of the contamination. Finally, if the victims were exposed through ingestion, then consider the possibility that secondary exposure will occur during gastric lavage.

Competing interests

The author(s) declare that they have no competing interests.

References

1. Okumura T, Suzuki K, Fukuda A, Kohama A, Takasu N, Ishimatsu S, Hinohara S: **The Tokyo Subway sarin attack: disaster management. Part II. Hospital response.** *Acad Emerg Med* 1998, **5:** 618-624.
2. Okumura T, Suzuki K, Fukuda A, Kohama A, Takasu N, Ishimatsu S, Hinohara S: **The Tokyo Subway sarin attack: disaster management. Part I. Community emergency response.** *Acad Emerg Med* 1998, **5:**613-617.
3. Okudera H: **Clinical features on nerve gas terrorism in Matsumoto.** *J Clin Neurosci* 2002, **9:**17-21.
4. Okudera H, Morita H, Iwashita T, Shibata T, Otagiri T, Kobayashi S, Yanagisawa N: **Unexpected nerve gas exposure in the city of Matsumoto: report of rescue activity in the first sarin gas terrorism.** *Am J Emerg Med* 1997, **15:**527-528.
5. Nozaki H, Hori S, Shinozawa Y, Fujishima S, Takuma K, Ohki T, Suzuki M, Aikawa N: **Secondary exposure of medical staff to sarin vapor in the emergency room.** *Intensive Care Med* 1995, **21:**1032-1035.
6. Locky D, Davis G: **The challenges of deliberate chemical/biological attack.** *Resuscitation* 2003, **58:**293-296.
7. Treat KN, Williams JM, Furbee PM, Manley WG, Russell FK, Stamper CD Jr: **Hospital preparedness for weapons of mass destruction incidents: an initial assessment.** *Ann Emerg Med* 2001, **38:**562-565.
8. Ghilarducci DP, Pirrallo RG, Hegmann KT: **Hazardous materials readiness of United States level 1 trauma centers.** *J Occup Environ Med* 2000, **42:**683-692.
9. Wetter DC, Daniell WE, Treser CD: **Hospital preparedness for victims of chemical or biological terrorism.** *Am J Public Health* 2001, **91:**724-726.
10. Schultz CH, Mothershead JL, Field M: **Bioterrorism preparedness I: the emergency department and hospital.** *Emerg Med Clin N Am* 2002, **20:**437-455.
11. Macintyre AG, Christopher GW, Eitzen E, Gum R, Weir S, DeAtley C, Tonat K, Barbera JA: **Weapons of mass destruction events with contaminated casualties: effective planning for health care facilities.** *JAMA* 2000, **283:**242-249.
12. Georgopoulos P: **Hospital response to chemical terrorism: personal protective equipment, training, and operations planning.** *Am J Ind Med* 2004, **46:**432-445.
13. Levitin H, Siegelson H: **Hazardous materials.** *Emerg Med Clin* 1996, **14:**727-348.
14. White SR, Klein KR, Eitzen EM: **Disaster management for chemical agents of mass destruction.** In *Emergency Medicine: A Comprehensive Study Guide*, 6th ed. New York: McGraw-Hill; 2004:42-46.
15. Hirose Y, Kinoshita H, Tanaka T, Hata K, Yamazaki Y, Honda T: **Secondary poisoning in a healthcare worker resulting from reaction between a toxic agent and gastric acid.** *J Jap Assoc Acute Med* 2000, **11:**528.
16. Kinoshita H, Hirose Y, Tanaka T, Yamazaki Y: **Oral arsenic trioxide poisoning and secondary hazard from gastric content.** *Ann Emerg Med* 2004, **44:**625-627.
17. White SM: **Chemical and biological weapons. Implications for anaesthesia and intensive care.** *Br J Anaesth* 2002, **89:**306-324.