Preparedness for Terrorism: Managing Nuclear, Biological and Chemical Threats

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Abstract

The management of nuclear, biological and chemical (NBC) terrorism events is critical to reducing morbidity and mortality in the next decade; however, initial patient care considerations and protective actions for staff are unfamiliar to most front-line clinicians. High explosive events (bomb and blast) remain the most common type of terrorism and are easy to detect. Conversely, some types of terrorist attacks are more likely to be unsuspected or covert. This paper explains the current threat of terrorism and describes clues for detection that an event has occurred. Specific criteria that should lead to a high suspicion for terrorism are illustrated. The manuscript outlines initial actions and clinical priorities for management and treatment of patients exposed to nuclear/radiological, biological, chemical and combined agents (for example an explosion involving a chemical agent). Examples of terrorist events include: a nuclear explosion, an aerosolised release of anthrax (biological), dissemination of sarin in a subway (chemical), and the detonation of a radiologic dispersion device or "dirty bomb" (combined explosive and radiological). Basic principles of decontamination include potential risks to healthcare providers from secondary exposure and contamination. Unique issues may hinder clinical actions. These include coordination with law enforcement for a crime scene, public health entities for surveillance and monitoring, hazardous materials teams for decontamination, and the media for risk communications. Finally, the importance of personal preparedness is discussed.

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Introduction

Preparedness for terrorism in the 21st century includes addressing the management of nuclear, biological and chemical (NBC) terrorism events. Understanding the terrorist threat and detecting clues that an attack has occurred are critical to reducing morbidity and mortality in the next decade. While high explosive events (bomb and blast) remain the most common type of terrorism and are easy to detect, a higher index of suspicion is required to identify NBC attacks. Familiarity with initial patient care considerations and protective actions for staff including decontamination techniques is essential for front-line clinicians. In addition to identifying victims of an NBC attack, personal preparedness for healthcare providers and their families is paramount.

Preparedness for Terrorism: Managing Nuclear, Biological, Chemical (NBC) Threats

Understanding the Terrorist Threat

The strike on the World Trade Center and the Pentagon on 11 September 2001 and subsequent anthrax letter attacks that fall in the United States refocused the world's attention on the reality of terrorist attacks against a civilian population. Daily life was changed forever with the implementation of unprecedented security measures at many locations such as airports. The threat of suicide bombers — where human beings are used as weapons – is virtually impossible to mitigate in free societies. These explosive incidents can have secondary NBC effects such as transmission of the biological agent hepatitis through infectious shrapnel (i.e., the bone of the infected suicide bomber) as has been reported in Israel.

The Global Incident Map[1] displays the enormity of the current global threat of terrorism and other suspicious events. While conventional terrorism (bomb and blast) remains the most common, the focus of the paper is the relatively less well understood threat (outside of military situations) of nuclear/radiological, chemical and biological or NBC terrorism.

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Nuclear/Radiologic Terrorist Threats

Terrorism involving radiation may be "overt," such as a nuclear bomb explosion, or "covert" such as when radionuclear materials are released surreptitiously through a ventilation system or food or water supply. The classic mushroom cloud following a nuclear explosion would be an easily detectable catastrophic event, whereas the unannounced release of radionuclides in water, food or air would be odorless, colorless and tasteless; thus a high degree of suspicion would be necessary for detection. A third type of radiation event would be with a combined weapon or radiological dispersion device (RDD), often called a "dirty bomb." This would be a mixed covert and overt situation. The explosion from the bomb itself would be rapidly detected; however, first responders would need to use radiation detection equipment to determine that radiation was present.

Biological Terrorist Threats

With the exception of an event similar to the anthrax letter incidents in the fall of 2001 in the US that behaves much like a chemical event (described later), terrorist use of biological weapons would likely be through aerosol dissemination. Terrorists would first convert the biological agent into a form that could be spread through the air or "weaponise" it; this would enable a large number of persons to be exposed after a single release. World Health Association modelling predicts that 50 kg of anthrax or tularemia aerosolised over an urban population of 5 million would result in 250,000 persons contracting disease. For anthrax, there would be an estimated 100,000 deaths compared with 19,000 deaths for tularemia.[2]

Chemical Terrorist Threats

As opposed to an aerosolised release of a biological agent over an open area, a chemical terrorist attack is more likely to occur within an enclosed space such as a shopping mall or indoor sporting facility. This is because the effects of chemicals will dissipate rapidly when victims are removed from the area of exposure. The sarin attack on the Tokyo subway is a stark reminder of the potential effects of a chemical agent released on a civilian population.[3] Another technique used by terrorists is that of a combined weapon. In the case of chemicals, this could include detonation of an existing structure such as a fixed chlorine tank or chemical cargo being transported near a highly populous centre via train or truck.

Clues to Detection and Diagnosis

Since terrorism is a relatively rare event, the first priority is to detect what has occurred and assess the risk. As mentioned, a nuclear explosion would be obvious; however, an RDD would require the use of radiation detectors such as Geiger counters to detect. In addition to these hand-held detectors, healthcare facilities may have fixed detectors, for example, mounted discretely in the ceiling of the emergency department. Patient clinical presentation may provide additional clues that a radiation incident has occurred. If a patient presents with a burn-like wound without a history consistent with a burning injury, the clinician should inquire about radiation exposure. Unless radiation exposure is high, patients may not experience immediate symptoms.

The detection of a biological event is much more challenging than for a radiological incident. As for radiation, hand-held detectors exist, but they are much less sensitive than radiation detectors. Clinicians must therefore rely on epidemiological evidence. Clues that a bioterrorism attack has occurred include:

- Increased deaths in animal populations
- Disease presenting in the wrong season or geographical location, e.g. multiple influenza patients at an unexpected time of year
- Single case of an uncommon disease, e.g. smallpox
- Clusters of similar symptoms in persons recently at same location

Most patients infected with biological terrorism agents present with non-specific influenza-like symptoms, after an incubation period that is generally several days after the attack. If a cluster of such patients occurs, an epidemiologic investigation is essential. Public health entities in many countries have surveillance systems in place (e.g., the US BioWatch program);[4] however, their efficacy is uncertain and it may be an astute clinician who first alerts authorities to the need to investigate.

Chemical agent attacks should be readily detectable. Symptoms are characteristically rapid in onset and there will be multiple people at same location with similar presentations. Classic "toxidromes" (constellations of signs and symptoms specific to a certain exposure) occur, for example, seizures or fasciculations and drooling. Hand-held detectors exist and are technologically more accurate than hand-held biological detectors, but less reliable than radiation detectors.

There are 4 basic clinical syndromes that may occur after exposure to a chemical agent: asphyxiation; cholinesterase inhibition (nerve agents); pulmonary irritation (choking agents); and vesication (blister agents). Each type of chemical produces distinct signs and symptoms.

Chemicals that cause asphyxiation syndromes result in cardiovascular and central nervous system derangements. Nerve agents produce miosis, secretions, fasciculations, rhinorrhoea, wheezing, and seizures. Cough, chest tightness, wheezing, and non-cardiogenic pulmonary oedema are typical presentations after exposure to choking agents.

Table 1. Chemical versus Biological Terrorism Attack Characteristics

Chemical	**Biological**
Immediate symptoms	Symptoms delayed
Lights and siren response	Public health emergency/ epidemiologic investigation
Discrete location(s)	Initial cases may be unrecognised
Easily detected	Detection more difficult
Secondary contamination	Only a few are contagious

Table 2. Critical Actions for Nuclear, Biological and Chemical (NBC) Incident Management

Evacuate and secure area
Activate emergency operations
Dispatch response teams
Crisis and emergency risk communication
Do confirmatory testing
Monitor health (short-term)
Begin long-term surveillance and sampling
Address mental health issues

Finally, blister agents lead to eye injuries and vesicular skin lesions.

Table 1 depicts the major differences between a typical chemical and biological terrorism event. Whereas secondary contamination of healthcare workers from chemical agents is a major concern, few of the high-threat biological terrorism agents are contagious from person-to-person so provider protection is less challenging. Notable exceptions of biological agents that are transmissible include smallpox, pneumonic plague, and the viral haemorrhagic fevers.

Initial Patient Management

When managing patients with chemical, biological, or radiologic agent exposures, the first priority is protection of the healthcare provider. Secondary contamination or exposure can have immediate or long-term medical and health effects on first responders and first receivers that may render them incapable of direct patient care after the event or may have delayed consequences. Patients should be removed from continuing exposure to the NBC agent and providers should don personal protective equipment (PPE) specific to the agent type.[5] Hazardous materials teams should perform decontamination when indicated.

Concurrent with assuring healthcare provider safety, personnel should activate the disaster or "emergency management" plan. An Incident Management System such as the Hospital Incident Command System or HICS[6,7] should be used to clearly define the command and control structure and coordinate resources. In this way, individuals will understand their specific roles and responsibilities and resources can be applied to optimise patient outcomes.

When multiple victims are present, disaster triage[8] should be performed to prioritise patients for care. In the NBC environment, healthcare providers will need to coordinate medical actions with non-traditional partners such as public health, the military, the media and law enforcement. A terrorist attack means that there will be a crime scene and the mission of law enforcement personnel will include evidence collection. Drills that train front-line healthcare providers in how to manage an event in collaboration with important partners will make conflicts in prioritisation of life-saving patient care less likely. Table 2 lists additional important actions for initial and ongoing management of an NBC incident.

Nuclear/Radiological

Initial patient management for nuclear/radiologic events includes applying the principles of "time – distance – shielding," i.e., minimise the time of radiation exposure, increase the distance from the radiation source, and shield people from radiation. While patients require decontamination after an RDD or "dirty bomb" incident, treat traumatic injuries first as the radiation exposure is typically minimal and therefore of less concern than instant mortality from bomb and blast effects.[9] Exposures to most radionuclides do not require immediate treatment. One exception is that if I-131 is used (unlikely in an RDD scenario), KI treatment for persons under 40 years of age is recommended. This is the reason that in some systems members of the public are provided with potassium iodide tablets if they live within 10 miles of a nuclear power plant in case of an accidental release of radiation.

As most physicians are unfamiliar with radiation injuries, the hospital health physicist or radiation safety officer is an important resource for technical information. This person can provide Geiger counters and other methods to measure radiation exposure. Clinicians should confirm the history and evidence of exposure; perform a radiologic survey; process biological samples such as complete blood counts (an absolute lymphocyte count decrease in 6 to 48 hours predicts toxicity) and swab all body orifices. In severe cases, patients may require bone marrow transplants. If internal radiation contamination is suspected, providers should collect urine, faeces, emesis, and any metal items. Specific antidotes (e.g., KI to protect the thyroid) should be considered.

Additional considerations for the initial management of patients exposed to radiation include that emesis predicts toxicity (immediate and up to 2 hours post-exposure indicates a significant radiation exposure) and "exposed" (irradiated) patients are not "radioactive" as compared with externally or internally "contaminated patients." Healthcare providers must wear protective gear when decontaminating patients.

Biological

The first challenge for initial patient management after biological agent exposure is realising that an attack has occurred. Since the clinical manifestations of most biological agents involve non-specific influenza-like illness presentations, clinicians must suspect that a terrorist agent was released. Once this is considered, public health authorities must immediately be activated to begin an epidemiologic investigation along with law enforcement to perform a criminal investigation. Clinicians must know how to access these entities 24 hours per day.

Patients with contagious infectious diseases should be isolated and staff must wear appropriate PPE to prevent the spread of disease. A system should be in place to provide prophylactic antibiotics and antiviral medications to exposed but non-ill patients and healthcare personnel. In addition, stockpiles of medications and equipment must be available for therapeutic use. In many cases, supportive care in an intensive care unit setting (often involving ventilation) will be necessary. An aerosolised release of a weaponised biological agent can result in tens of thousands of casualties.

While the surreptitious release of an aerosolised biological weapon would result in the greatest numbers of exposed persons, an overt release such as occurred with the anthrax letter attacks in the US in the fall of 2001 is also possible. Copycat incidents may follow such an attack and the emergency response system can become overwhelmed with multiple hoaxes and false alarms requiring a massive expenditure of resources even when no actual attack has occurred. This can divert critical assets from truly exposed and ill patients.

Chemical

Patients exposed to chemical terrorism agents experience immediate symptoms. Initial management includes moving affected persons out of enclosed spaces and upwind of the area of contamination. Patients require prompt decontamination. The chemical agent should be identified if possible.

Sarin is a nerve agent that is similar to organophosphates, but more potent. It is a clear, colorless, odorless, tasteless liquid that can evaporate into a vapour. Exposure occurs through skin and eye contact, by inhalation, and also through ingestion of contaminated food and water. Sarin blocks the enzyme acetylcholinesterase leading to excess acetylcholine at synaptic nerve clefts. This produces a life-threatening cholinergic syndrome. Sarin alters cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects) and at skeletal myoneuronal junctions and autonomic ganglia (nicotinic effects), and the central nervous system.

Symptoms manifest within a few seconds of vapour exposures and clothing can release sarin for about 30 minutes after being in contact with vapour. Symptoms occur within a few minutes and up to 18 hours after liquid exposures. Sarin produces both muscarinic and nicotinic effects (Table 3). It is the most volatile of the nerve agents; it quickly evaporates from a liquid into a vapour and spreads. Therefore the effects are immediate, but short-lived. Treatment options after sarin exposure are outlined in Table 4.

A notable example of a chemical terrorist attack against a civilian population was the sarin attack in Tokyo, Japan in 1995 carried out by the cult religious group Aum Shinrikyo in which 12 persons died, more than 5000 were injured and over 1000 were hospitalised.[3] A major challenge after this attack on the Tokyo subway was that of secondary contamination of healthcare personnel. Of the 1364 emergency medical technicians dispatched to the scene, 135 were secondarily affected. At the St. Luke's International Hospital where 640 patients were received, 23% of the medical staff complained of symptoms and had signs of secondary exposure. There were no deaths from secondary contamination in this case, but there would have been if 100% sarin solution had been used rather than a more dilute form.

Researchers made several important observations after analysis of the sarin attack.[3] These included that: 1) many severe victims were transported to the nearest hospital

Table 3. Clinical Manifestations of Sarin Exposure

Muscarinic	**Nicotinic**
Diarrhoea	Weakness
Urination	Hypertension
Miosis	Mydriasis
Bradycardia, Bronchorrhoea	Tachycardia
Bronchospasm	Fasciculations (followed by flaccid paralysis, similar to the effects of succinylcholine)
Emesis	
Salivation, Secretion, Sweating	

Table 4. Treatment Options after Sarin Exposure

Advanced Cardiac Life Support and Intubation

Antidotes

- Atropine (0.1 mg/kg IV or IM) (Anticholinergic; Muscarinic receptors as acetylcholine antagonist, no effects on muscle weakness or respiratory arrest)
- Pralidoxime (2-PAM) (50 mg/kg IV or IM) (Acetylcholine reactivator, Nicotinic receptors)
- MARK I kit (autoinjectors with 2 mg atropine/600 mg 2-PAM)

Diazepam (5 to 10 mg IV in adults and 0.2 to 0.5 mg/kg in children for seizure treatment)

Topicamide and phenylephrine eye drops (to alleviate pain from ciliary spasm) rather than being dispersed to multiple available facilities in the region; 2) first responder and hospital staff were not adequately educated and trained in the care of chemical weapons casualties; 3) hospitals lacked detection and identification capabilities; 4) at least 110 medical staff working in the fire department and main receiving hospital in Tokyo received secondary exposures; and 5) there was a lack of decontamination facilities and protective equipment.

Decontamination Techniques

The purpose of decontamination is to reduce or prevent further absorption and subsequent toxicity of the NBC agents for patients and avoid secondary contamination of healthcare providers. In addition, ensuring that victims do not enter the healthcare facility prior to decontamination can prevent unnecessary closure of an emergency department or entire hospital. This would avoid associated costs of later decontamination as well as decreased patient care revenues and a blemished hospital reputation.

Healthcare facility decontamination systems[10] with their respective advantages and disadvantages include: fixed systems (no assembly time; expensive, takes up space, needs 24/7 access); mobile trailers (packaged all together; needs storage space, 24/7 driver); tent or constructed facility (inexpensive, can be set up in various locations; less durable, need rapid access); combination systems such as permanently fixed warm water showers on the side of a building; or something as simple as a wading pool and a hose.

The most critical action for decontamination is the removal of patients' clothing. This will eliminate at least 70% to 85% of contaminants. Soap and water can then be used to remove most types of additional toxins. The most important decontamination principle is summarised by the key phrase, "strip and shower".[11]

Personal Preparedness

Healthcare personnel will only be ready to care for patients affected by NBC terrorism agents if they prepare themselves and their families prior to an event. This will lead to increased confidence and comfort levels as well as decreasing absenteeism. Several excellent web links exist with details of how to best prepare including http://bepreparedcalifornia.ca.gov/ (see left side of page under links to further information) and http://www.redcross.org/ (see navigation bar on left side under "Get Prepared").

Conclusion

While high explosive bomb and blast events remain the most common type of terrorism, practising clinicians should understand the unique threat of terrorism from the use of NBC agents.[12-14] This includes clues to detection and diagnosis and a solid grasp of initial patient management actions. Protection from secondary contamination and exposure as well as knowledge of options for decontamination are essential. Personal and family preparedness for disasters are key.

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REFERENCES

1. The Global Incident Map. Available at: http://www.globalincidentmap.com/map.php. Accessed 21 July 2009.
2. Health Aspects of Chemical and Biological Weapons. 1st ed. World Health Organization, United Nations, 1970. Available at: http://www.who.int/csr/delibepidemics/biochem1stenglish/en/index.html. Accessed 24 July 2009.
3. Okumura T, Suzuki K, Ishimatsu S, et al. Lessons learned from the Tokyo subway sarin attack. Prehosp Disast Med 2000;15:s30.
4. US Biowatch program. Available at: http://www.fas.org/sgp/crs/terror/RL32152.html. Accessed 21 July 2009.
5. Koenig KL, Boatright CJ, Hancock JA, Denny FJ, Teeter DS, Kahn CA, et al. Health care facilities' "war on terrorism": a deliberate process for recommending personal protective equipment. Am J Emerg Med 2007;25:185-95.
6. State of California, EMSA, Disaster Medical Services Division - Hospital Incident Command System (HICS). Available at: http://www.emsa.ca.gov/hics/. Accessed 24 July 2009.
7. Hick JL, Koenig KL, Barbisch D, Bey T. Surge capacity concepts for healthcare facilities: The 'CO-S-TR' model for initial incident assessment. disaster medicine and public health preparedness. Disaster Med Public Health Prep 2008;2 Suppl 1:S51-7.
8. Cone DC, Koenig KL. Mass casualty triage in the chemical, biological, radiological, or nuclear environment. Eur J Emerg Med 2005;12:287-302.
9. Koenig KL, Goans RE, Hatchett RJ, Mettler FA Jr, Schumacher TA, Noji EK, et al. Medical treatment of radiological casualties: current concepts. Ann Emerg Med 2005;45:643-52.
10. Koenig KL, Boatright CJ, Hancock JA, Denny FJ, Teeter DS, Kahn CA, et al. Health care facility-based decontamination of victims exposed to chemical, biological, and radiological materials. Am J Emerg Med 2008;26:71-80.
11. Koenig KL. Strip and shower: the duck and cover for the 21st century. Ann Emerg Med 2003;42:391-4.
12. Hatchett RJ, Kaminski JM, Goans RE. Nuclear and radiological events. Chapter 30. In: Koenig KL, Schultz CH, editors. Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices. Cambridge University Press, 2010.
13. Darling RG, Woods JB, Cieslak CJ. Biological events. Chapter 29. In: Koenig KL, Schultz CH, editors. Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices. Cambridge University Press, 2010.
14. Urbanetti J. Clinical aspects of large-scale chemical events. Chapter 28. In: Koenig KL, Schultz CH, editors. Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices. Cambridge University Press, 2010.