SPECIAL REPORT

Decontamination of Mass Casualties — Re-evaluating Existing Dogma

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Abstract

The events of 11 September 2001 became the catalyst for many to shift their disaster preparedness efforts towards mass-casualty incidents. Emergency responders, healthcare workers, emergency managers, and public health officials worldwide are being tasked to improve their readiness by acquiring equipment, providing training and implementing policy, especially in the area of mass-casualty decontamination. Accomplishing each of these tasks requires good information, which is lacking. Management of the incident scene and the approach to victim care varies throughout the world and is based more on dogma than scientific data. In order to plan effectively for and to manage a chemical, mass-casualty event, we must critically assess the criteria upon which we base our response.

This paper reviews current standards surrounding the response to a release of hazardous materials that results in massive numbers of exposed human survivors. In addition, a significant effort is made to prepare an international perspective on this response.

Preparations for the 24-hour threat of exposure of a community to hazardous material are a community responsibility for first-responders and the hospital. Preparations for a mass-casualty event related to a terrorist attack are a governmental responsibility. Reshaping response protocols and decontamination needs on the differences between vapor and liquid chemical threats can enable local responders to effectively manage a chemical attack resulting in mass casualties. Ensuring that hospitals have adequate resources and training to mount an effective decontamination response in a rapid manner is essential.

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Abbreviations:
AIWW = Ambulatory Injured and Ambulatory Worried Well Non-Injured
ATSDR = [US]Agency for Toxic Substances Disease Registry
EMS = Emergency Medical Services
GB = sarin
HazMat = hazardous materials
HRSA = [US]Health Resources and Services Administration
ICU = intensive care unit
MCI = Mass-Casualty Incident
PPE = personal protective equipment
SBCCOM = US Army Soldier and Biological Chemical Command
US = United States of America

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Introduction

A tanker truck carrying 10,000 gallons of fuming sulfuric acid ruptures in a motor vehicle collision while traveling through the downtown area on a cool April afternoon. A cloud of chemical vapor bellows out from the wreckage and travels downwind towards a nearby lake and shopping center. Bystanders hear the impact and begin running toward the scene, but quickly turn and run when they start feeling the ill effects of the chemical vapor. Fire and law *enforcement units are urgently dispatched to the scene, and implement their incident command system. Ambulatory survivors are strongly encouraged to remain at the scene, upwind from the release. Hazardous material (HazMat) teams set up decontamination showers, shelters, trailers, and various water-spraying apparatuses. Victims receive triage tags, move towards the decontamination area, and are instructed to remove their clothing. After washing, emergency medical services (EMS) personnel assess the victims' medical condition.*

This is a typical hazardous materials (HazMat) response scenario exercised regularly throughout the world by emergency responders and hospital personnel. Many consider this approach to be scientifically based and generally accepted. Management of the accident scene and the approach to victim care, however, varies throughout the world, and is based more on personal experience and gut instinct than on scientific data.

In order to plan effectively for and manage a HazMat event with massive numbers of casualties, we must critically assess the criteria upon which we base our response. Do all of the victims of a similar HazMat exposure require a soap and water shower? If so, how long should they be showered and what technique works best? If not, what might reasonably be accomplished? Is the response altered by the numbers of victims and their complaints? How do inherent delays in setting up decontamination equipment at the scene impact victim compliance with decontamination, the decision to provide water decontamination, and ultimately victim care? Is clothing removal alone sufficient? Will affected individuals remove their clothing and remain at the scene for decontamination? What level of personal protective equipment (PPE) should first-responders use? What about hospital personnel? How would scene management be affected if the outside temperature was below freezing? What minimum level of decontamination preparedness should be expected in all communities?

Hazardous materials represent a complex and significant hazard for emergency responders and healthcare workers. Situations involving exposures to hazardous materials are relatively rare events, but they represent one of the most common events that occur in the community setting.[1-4]

The threat of a terrorist attack utilizing hazardous materials has reshaped the focus of community preparedness, and has resulted in increased spending on decontamination equipment and protective gear. Attention towards HazMat protection increased after the intentional nerve agent release in Tokyo in 1995 by a fanatical cult. Governments, especially in the United States of America (US), expanded federal agency, manpower, and budgetary commitments in this regard after the World Trade Center and Pentagon attacks and the intentional use of anthrax, all of which occurred during the fall of 2001.

While the spending and accumulation of decontamination and personal protective equipment proceeds, little attention has been placed on the actual decontamination process. Areas of controversy include: (1) differences in management priorities for a community HazMat event (i.e., liquid, powder, vapor, or gas exposure) versus a chemical, mass-casualty incident (i.e., vapor or gas exposure); (2) obstacles to delivering care during a large-scale event; (3) definition of successful decontamination modified by location, weather, personnel, equipment, and the actual volume of victim need.

The potential for a hazardous materials incident, either accidental or intentional, is significant. In the United States, the Environmental Protection Agency estimated that approximately 850,000 facilities manufacture, store, or utilize hazardous or extremely hazardous substances. Many of these sites are located in urban areas with populations at risk exceeding one million.[1] More than 4 billion tons of chemicals are transported annually by air, surface, and water.[2] Although terrorists might manufacture their own chemicals, it might be more likely that they will utilize the presence of existing stored or transported chemicals to complete their attack.[5,6]

This paper reviews current standards surrounding the response to a hazardous materials release resulting in the production of massive numbers of exposed human survivors. In addition, a significant effort is made to prepare an international perspective on this response.

Decontamination

Decontamination is a process of removing or reducing the concentration of harmful substances. It should be performed whenever there is a likelihood of contamination or risk of secondary exposure. In this paper, the discussion is limited to the decontamination of humans after exposure to a hazardous substance.

A person may become contaminated by contacting chemicals in the form of a vapor, gas, mist, solid, or liquid from the actual source or from others who already are contaminated. Agents can be removed by physical means (clothing removal), absorption (Fuller's earth), dilution (water showering), or by neutralizing the chemical.[1–4,7] In airborne releases involving gases or vapors, which are the most common occurrence in HazMat incidents that result in human injuries, evacuation from the source and removal of clothing typically is all that is needed to prevent further exposure or injury.[7–8]

Victim or responder decontamination is an organized method of removing residual contaminants from clothing and skin. The most important step in decontamination is the speed of the removal of the agent.[8] Thus, any organized effort for decontamination should have the capability to enable the victims to remove their clothing as rapidly as is possible after exiting the contaminated area.

After a liquid or powder exposure, decontamination is accomplished best by first removing and containing the victim's clothing, and then rinsing the individual(s) with large quantities of water (high volume, low pressure). This procedure is performed best within minutes of skin contact to minimize the degree of injury and clinical sequelae. Gently scrubbing the skin with soap and a soft brush removes any remaining fat-soluble chemicals and solid materials. The need to contain the runoff versus allowing it to flow into the sewer system varies throughout the world, and is based more on practicality than regulatory guidance.[9]

Copious skin lavage and wound irrigation with water after chemical contact has proven to be beneficial for both liquid and solid substances. This procedure remains the cornerstone of chemical burn management and victim decontamination.[10–13] Copious irrigation cleans the skin of unreacted surface chemical, dilutes the chemical already in contact, decreases its duration of skin contact, and in the case of corrosives, helps restore tissue to its normal pH thereby reducing the incidence of full-thickness burns.[3,10,14] The same rule applies to associated ocular injuries, which are common with chemical skin burns and open wounds. To minimize injury, the time interval between contamination and the start of irrigation must be as short as possible.[10,15] Time and resource constraints at the scene only may allow a quick gross field decontamination that will need to be followed by a thorough washing at the hospital.

Individuals who have been exposed to vapor do not require skin decontamination. Removal from the atmosphere containing the vapor and possibly the removal of clothing prior to entering a bus, ambulance, or hospital is all that is necessary.[16] Procedures that detain ambulatory victims in order to direct them through a mass showering system (tents, trailers, etc.) may needlessly delay evacuation and treatment.[16] Delaying or improperly conducting decontamination may inadvertently increase the dangers to the patient as well as to the other emergency (healthcare) providers.[16]

There are >25,000 different products that are capable of producing chemical burns.[15] The intensity of the chemical injury is determined by its concentration and reactivity, pH, duration of skin contact, and the integrity of the skin.[13,15,17,18] When the duration of skin contact is prolonged, the potential for tissue damage and toxicity may be worsened by direct injury and systemic absorption. Agents such as corrosives and solvents directly damage the anatomical makeup of the skin, while other hazardous materials such as pesticides, hydrogen fluoride, and phenolic substances penetrate tissues, enter the circulation, and cause systemic toxic effects.[3] For example, malathion penetrates the skin almost immediately upon contact.[17]

Most experimental studies have shown advantages of skin irrigation within the first 10 minutes of contact. For corrosives, especially alkali, the beneficial effects could be seen for periods of up to one hour.[11] When animal skin contaminated with the nerve agent sarin (GB) was flushed with water at two minutes, 10.6 times more GB was required to produce the same mortality rate as when no decontamination was performed.[7] Delayed decontamination still may be beneficial to the skin as well as for minimizing the risk of secondary contamination, but treatment within the first hour (which some call the "golden hour") following injury is of major importance in altering the severity of the burn.[10–11]

Water as a diluent is contra-indicated (in theory) in only a few rare situations involving metallic sodium, potassium, lithium, cesium, and rubidium, all of which react violently with water. Dusts of pure magnesium, white phosphorus, sulfur, strontium, titanium, uranium, zinc, and zirconium will ignite on contact with air. If any of these metallic substances are present on the victim's skin, a chemical reaction already will be occurring while the proper method of decontamination is being considered. Despite the potential for reaction, flushing the victims with large quantities of water will minimize the ensuing harm. It is essential, however, that the victim or responders remove contaminated clothing prior to the water decontamination in order to decrease the likelihood of skin burn. When possible, these substances can be removed physically with forceps and stored in a receptacle containing mineral oil.[1,15,19]

In addition to water (or soap and water), other topical decontaminants have been used first to either absorb or detoxify the hazardous agent prior to showering. Examples include flour (followed by wiping with wet tissue), Fuller's earth (diatomaceous earth), Dutch Powder, foams, catalytic solvents, and gels. These absorbent decontaminants work by reducing the quantity of chemical agent available for uptake by the skin. They have no efficacy against agents already absorbed through the skin.[7] The ideal cleaning agent or topical decontaminant is inexpensive and non-toxic, can be applied rapidly with minimal to no preparation time, requires low volumes, and is able to effectively remove the entire surface contaminant.

The military uses a M291 resin kit, a universal, dry decontaminant for spot decontamination of skin, and 0.5% hypochlorite for chemical warfare and biological agents. Hypochlorite, used since World War I, acts universally against organophosphates (nerve agents) and vesicants (blistering agents), if applied in a timely manner.[7]

While bleach is an effective detoxifying agent, there are some serious concerns regarding its use. It irritates the skin, which may allow the chemical warfare agent to be absorbed at a faster rate. In addition, in order to maintain its effectiveness, the bleach solution must be made daily or even more frequently, especially in warm environments where evaporation may occur.[7] Finally, bleach sensitizes skin, and is toxic if applied to open wounds or the eye.

Despite these drawbacks, some emergency responders still recommend the use of bleach. A number of commercial vendors sell bleach-containing sprayers and decontamination systems that infuse bleach or chlorine through the shower. None of these systems have proven to be more beneficial than the routine use of soap and water. The time required to set up these systems actually may delay the showering process, and the addition of bleach may be corrosive to decontamination equipment.

The quality of decontamination performed depends on the situation. In general, removing and bagging the victim's garments eliminates 80–90% of the contaminants, and minimizes the risk of spreading the toxic agent to others.[1-4,16] This percentage depends upon the amount of clothing the victim is wearing at the time of exposure. These data come from the radiation management community, and are based on the rule of nines for skin burns.

Clothing has been reported to enhance chemical absorption by acting as an occlusive dressing. Occlusion changes the hydration and temperature of the skin: factors that affect skin absorption. Failure to quickly remove one's contaminated clothing also may prevent evaporation of volatile agents.[17–20] It may be difficult to prove whether or not a victim from a terrorist attack has been exposed to a chemical. Responders and hospital personnel should assume that these victims are contaminated, since it takes too long to prove that they have not been contaminated. Thus, clothing removal is the minimum level of decontamination that is acceptable after exposure to a hazardous chemical, radioactive contamination source, or terrorist attack.

Once removed, the contaminated clothing either should be double bagged or placed in an airtight container and handled as hazardous waste. The clothing should not be transferred with the patient in the bus or ambulance, as this could expose the patient, the responders, other survivors, or hospital personnel to the chemical. The bag of clothing should be left at the scene and managed by the fire department or law enforcement.

What are the risks of showering victims outside in cold weather? According to a recent report prepared by the US Army Soldier and Biological Chemical Command (SBCCOM) entitled, "Guidelines for Cold Weather Mass Decontamination during a Terrorist Chemical Agent Incident," the risk of hypothermia is minimal.[21] Regardless of the ambient temperature, the report states "people who have been exposed to a known, life-threatening level of chemical contamination should disrobe, undergo decontamination with copious amounts of high-volume, low-pressure water or alternative decontamination method, and be sheltered as soon as possible." It should be noted that, if the chemical is not known and there is no indication that the chemical is a life threat to the victim, hypothermia should not be risked to comply with the demand for shower decontamination. In some cases, it might be more prudent to remove the victim's clothing and achieve water decontamination in a more suitable environment.

In an article on mass decontamination after a chemical weapon attack, Lake noted that, "immediate decontamination only may involve removal of clothing unless victim is grossly contaminated with liquid agent."[8] Ambulatory victims exposed to a vapor or gas might only need to remove their clothing. Symptoms of exposure typically will improve once victims are removed from the scene. Lake also noted that the most important component of decontamination is the "speed of the removal of the agent."[8] Individuals with a liquid exposure will require a soap and water shower, but should do so after rapidly removing their clothing. When the ambient temperature is above 65°F (18.3°C), any form of outdoor decontamination is acceptable. At ambient temperatures above 35°F (1.7°C), victims need to be quickly moved into a heated building following outdoor soap and water decontamination.[21]

If the ambient temperature drops to freezing, outdoor water decontamination may create serious safety hazards and equipment failures associated with ice formation. Under these extreme weather conditions, contaminated outer garments need to be removed outside before bringing patients inside for showering.[21] Clothing removal needs to be completed quickly to minimize cold wind exposure. Although formal studies have not been performed, compliance with any request to remove clothing most likely is enhanced when privacy is respected and provided.

Decontamination for radiological agents parallels that for chemicals. If history, physical findings, or a significant positive reading from a radiation detector suggest radiation contamination, then the victim's clothing should be removed and contained. If victims are stable clinically, clothing removal is followed by a soap and water showering. If victims are unstable, life-saving intervention should be performed as soon as possible. Exposure to or contamination by radioactive materials should not delay life-saving intervention, but it is prudent and easy to remove clothing to protect the victim and the responders.

The Radiation Safety Officer should oversee the process and determine when the individual is free of radiation contamination. If the exposure to radioactive materials occurs in a controlled environment in which the contaminants are readily identified, then the victim can be managed as a pure radiation contamination or exposure victim. Since radiation contamination is non-volatile, it is not essential that these victims be decontaminated outside. If the circumstances are not clear, however, the contaminant should be considered "unknown", and treated as a chemical exposure. Ideally, the decontamination process then should be performed outside using the same equipment and protective gear recommended for chemicals.

Decontamination after exposure to biological agents is controversial. These agents are non-volatile and do not "off-gas." When these agents are deposited on the skin and clothing, they reportedly pose minimal risk of aerosolization either to the patient or to medical personnel. On the contrary, weaponized, non-static anthrax powder may behave as a vapor given its extreme ability to aerosolize. In either case, further study is in order. As a general rule, after a biological agent exposure, standard precautions should be followed. Unless the release is overt and the suspected contaminated individual arrives directly from the scene, no form of decontamination is required. If dermal contamination is suspected, the area should be washed using soap and water. A thorough rinse with a 0.5% bleach (hypochlorite solution), although possessing its own hazards, has been suggested to neutralize any remaining organism.[16]

Mass-Casualty Decontamination

Although few communities have developed a consistent unified system to provide care to victims of routine HazMat events, the current focus of most communities involves the creation of systems to provide decontamination to large numbers of casualties after an act of terrorism. The Aum Shinrikyo attack against Tokyo in 1995, dramatized the consequences of a terrorist attack utilizing a highly lethal chemical.[22] Military attacks against chemical depots in Croatia during the war in the Baltics are typical of the impact of using stored and transported industrial chemicals as weapons against civilians.[23]

How can communities develop a system of response that can meet the challenges of mass casualties with limited personnel, equipment, and budgets? How can communities handle hundreds or thousands of patients in a rapid, safe, and effective manner? How can communities become self-sufficient knowing that it may be hours before outside resources arrive?

First-responders must rapidly implement effective triage, provide appropriate decontamination, and effect rapid scene evacuation to maximize victim survival and responder safety. Determining how these processes are best

Questions
Will victims remove their clothing?
How long will victims remain at the scene awaiting decontamination?
What impact does modesty or inclement weather have on clothing removal?
Will ambulatory victims voluntarily proceed through a decontamination system?
How long should victims be showered and what water volume is required?
Are different procedures required for children, elderly, and special needs individuals?
What is the impact of inclement weather on victim management?
Is triage feasible during a chemical MCI? What are the criteria required to triage victims away from water decontamination?
What level of personal protective equipment (PPE) is required for responding personnel?
Can victims be effectively managed by and communicated to by responders dressed in chemical protective suits and respirators?
What is the minimum required ratio of responders to ambulatory and non-ambulatory victims in a chemical MCI?
What percent of victims should one anticipate to be ambulatory, semi-ambulatory, or non-ambulatory?
When performing mass-casualty decontamination, should victims be separated by gender, age, family, etc.?
In a chemical MCI, is any decontamination required beyond clothing removal, and if so, what are the criteria for deciding?

Table 1—Questions about decontamination that await further scientific evaluation (MCI = mass-casualty incident)

conducted during a chemical, mass-casualty incident (MCI) is controversial. There only is cursory consensus in this regard. The procedures have been utilized only infrequently, and thus, are not well understood, well-studied, or standardized. Current plans may reflect the inclinations of individuals or groups (dogma) rather than scientifically supported doctrines.

The generally accepted approach to mass-casualty decontamination is that all exposed victims must "strip and shower." This philosophy is based on a belief that one's approach to victim care in a large-scale chemical release is the same as the approach in a small community event, only bigger. In other words, regardless of the mechanism of exposure (liquid versus vapor), it commonly is believed that all victims of a HazMat release, large or small, require a traditional soap and water showering. As a result, suppliers have created and communities have purchased multi-casualty decontamination tents and trailers, and installed permanent facilities designed for soap and water decontamination of massive numbers of ambulatory patients within hospitals. In addition, governments have expended considerable resources training specialized regional response teams with the capability of providing these services.

Even though all of these approaches are based on a reasonable degree of logic, they are expensive, manpower-dependent, logistically challenging, and time-consuming. Their usefulness as an effective means of providing mass-casualty decontamination has not been demonstrated. As one author of this paper has stated, "large multi-casualty decontamination tents are too big for a routine community HazMat event, and too small for a large event." Even the effectiveness of using a fire hose to create a spray tunnel for victims to run through for mass decontamination has not been well-studied. Most victims are reluctant to remove their clothing in public. Some fire services have dealt with this hindrance by washing victims in their clothing. This actually may increase agent-skin contact.[16]

The [US]Agency for Toxic Substances Disease Registry (ATSDR) studied 13 states for seven years, and determined that in 90% of cases, only six or fewer human casualties required care after chemical exposures. In 70% of the cases, only two or fewer human casualties required care. Since injuries from hazardous materials accidents are rare, many hazardous materials response teams and hospitals have limited experience taking care of more than four or five victims.[24] Due to the rarity of chemical, mass-casualty incidents (MCIs), designing a study to evaluate an effective means of performing mass decontamination is difficult. As a result, recommended approaches to mass-casualty decontamination have been based on training exercises that typically use young, healthy (male) volunteers who remain at the scene as instructed, willingly remove their clothing (while their modesty is protected by wearing either a bathing suit or wet suit), and who stand in line in an orderly manner awaiting their soap and water shower. This typical exercise is applicable not directly to a heterogeneous, unprotected, symptomatic, undisciplined, multi-cultural, and multi-lingual population stressed by the event.

Government recommendations for mass-casualty preparedness stress that states must have the capacity to decontaminate a certain number of survivors. The [US]Health Resources and Services Administration (HRSA) Cooperative Agreement Guidance for national bioterrorism preparedness grants (02 May 2003) recommends:

> Portable or fixed decontamination systems for managing 500 adult and pediatric patients and health care workers per 1,000,000 population.

Is this recommendation for 500 ambulatory or non-ambulatory victims? Are all victims expected to "strip and shower?" What percent truly are injured or symptomatic? Although it is encouraging that the new recommendations move towards reasonable minimum levels of response, defining the capability of response systems requires further

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thought. As a result, developing a consensus to many of the questions listed in Table 1 is problematic due to the difficulty of obtaining reliable, scientific support for the conclusions.

Chemical MCI — Vapor vs. Liquid Exposure

Since it is difficult to study the approach to mass-casualty decontamination scientifically, maybe it is time to learn from the past. Historically, mass exposures to chemicals have been due to agents in the form of a gas or vapor, not liquid or solid. Examples include the use of chlorine, sulfur mustard, and phosgene during World War I; the release of methylisocyanate in Bhopal, India; chlorine release in Mississauga, Ontario; and the 26 July 1993 sulfuric acid release in Richmond, California.[7,25–26] More than 80% of survivors had been ambulatory and had minimal to no symptoms.[27]

Two recent events characterize the problems involved with a response to mass casualties after a vapor release. In an attack on a subway station in Montreal, Canada in September 2001, 175 people were held, against their will, for more than five hours while the cause of the release was determined.[28] A chemical exposure from a letter contaminated with kerosene caused over 50 employees of a bank in Memphis, Tennessee to be held, against their will, inside the bank for several hours while a plan of action was determined.

A vapor is the gaseous form of certain substances that normally exist as a solid or liquid at room temperatures and pressures. Some chemicals exist as vapors or gases at normal temperatures and pressures, and require high pressures to exist as a liquid during transport (chlorine, phosgene). Vapor pressures determine the tendency of a substance to evaporate, become airborne, and pose an inhalation threat.[29] The higher the vapor pressure, the more likely the substance will evaporate and form a vapor hazard.

A vapor will penetrate mucous membranes and act as a hazard to skin and lungs only in the event that the vapor is in sufficient concentration in the atmosphere near the victim. Once the victim is removed from the source of vapor, the chemical will not linger on the skin and its effects on the eyes and lungs will dissipate in most cases.[7] In fact, the chemical only will linger in the clothing. Once the clothing is removed, the process of decontamination is nearly complete. In some cases, thick hair might harbor some vapor. Removal of clothing should be considered the minimum level of decontamination for all victims of a chemical MCI (accidental or intentional).[20,30,31] Soap and water decontamination, although ideal, might slow the decontamination process, delay transfer from the scene, and utilize manpower that more appropriately might be directed towards the rescue and care of the non-ambulatory survivors. For vapor, soap and water might not be required.

Some chemicals, such as phosgene, will continue to have a deleterious effect on the victim's lungs possibly resulting in non-cardiogenic pulmonary edema and severe respiratory distress. But removing and containing the victim's clothing reduce the risk to the rescuer and the hospital.

In some cases, the chemical may exist as a liquid, but most of the victims will suffer exposure from the chemical as a vapor. In Tokyo, the Aum Shinrikyo released the nerve agent, sarin, as a liquid. Sarin evaporates at nearly the same rate as water. Thus, sarin fumes or vapors caused most of the injuries that resulted in 12 deaths and 37 critically ill patients that required the use of an intensive care unit (ICU) bed. Some 5,500 casualties presented to local hospitals and physicians for care. Over 30% of the first-responders and hospital personnel developed symptoms related to exposure to the sarin that remained in the victims' clothing.[22,30] Some of the victims actually contacted sarin in the liquid state: a few lived and a few died.[33] Phosgene, fuming sulfuric acid, and chlorine exist as a liquid in containers under high pressure. They are converted rapidly to a vapor with exposure to normal ambient pressures and become a vapor hazard. Even sulfur mustard, which is stored as a liquid and becomes a solid below 46°F (8°C), is used most effectively as a vapor for mass attacks.

Realistically, in a mass-casualty event, emergency medical services (EMS) and fire services will not be able to meet the immediate needs of most victims in office buildings, malls, schools, and other soft targets. If several sites are attacked at one time or if a cloud of chemicals or biologic particles blankets a city, first-responders will have a response capacity that is limited by personnel resources.

The major goal for responding agencies (and hospitals) will be to quickly identify, evacuate, decontaminate, and treat the symptomatic victims with obvious exposure to the hazard. Those with significant injuries typically are closest to the release (ground zero) and often need assistance to evacuate the area. Water decontamination, if required, should be reserved for this group of patients. Providing water decontamination in a timely manner, however, will be very difficult if water decontamination, which is heavily reliant upon large manpower and equipment resources, is directed towards the ambulatory survivors with minimal or no symptoms. To optimize the response, the mass-casualty plan must reasonably delineate protocols and procedures for delivering appropriate care to the following groups:

The Dead—These victims will not require immediate assessment or transport. They will be decontaminated at the scene or bagged and decontaminated at a separate location. They will not be transported by EMS or impact the hospital;

The Non-Ambulatory Injured—Although some of these victims may be transported by surviving victims to hospitals, most presumably will await rescue by fire and EMS personnel. Ideally, these casualties should be decontaminated prior to entering a bus or ambulance for transport. If these patients arrive at the hospital still in their clothing, they should be decontaminated prior to entering the hospital for care. This group of patients may require advanced levels of care, and therefore should be afforded preferred access to hospital beds. Historically, this group likely will make up a very small percentage of the survivors; and

The Ambulatory Injured and Ambulatory Worried Well, Non-Injured (AIWW)—These victims comprise the largest group (80–90% of survivors in most series), and either will wait for care at the scene, transport themselves, be transported by bystanders to the closest medical centers for care, or leave the scene and not seek care. They will evacuate the area of the chemical release, and thus, decrease their level of exposure and associated symptoms from the toxic vapor. Continued medical deterioration will depend on the toxicity of the chemical (i.e., phosgene, cyanide), and the amount of the vapor remaining on their clothing. Priorities for management include rapid evacuation from the hot zone, decontamination by removal of clothing, and evacuation to the cold zone or away from the scene of the attack. These victims should be afforded a sense of privacy so they can remove at least their outer clothing as quickly as possible. This will represent definitive decontamination for the majority of survivors in most cases.

A plan that triages the AIWW victims to a secondary location by bus or non-ambulance transport for collection of necessary personal data for law enforcement and public health officials, as well as secondary medical assessment by EMS personnel, will reduce the burden on EMS and the hospitals.

If the AIWW manage to leave the scene and arrive at a hospital for care, the hospital should activate its disaster plan, and direct all access through the emergency department. Their clothing should be removed as quickly as possible and contained outside the facility. The victim's personal items are carried with them in a sealed plastic bag. This procedure can be accomplished in most cases by the victims without assistance from medical personnel. This will reduce or eliminate exposure of triage personnel, therefore, minimizing the level of personal protective equipment required. Most or all of these victims will require no in-hospital treatment. Rapid triage assessment will determine which of the AIWW require further hospital assessment (lethargy, shortness of breath, vomiting) or transfer to a secondary location for data collection and secondary medical assessment. Thus, the advanced capabilities of the hospital are reserved for the more critically ill.

Triage that enables the more critically injured victims to access the hospital, and which refers other less injured or non-injured victims to a distant site could expose the triage officers to legal suit. It is essential that state legislatures or other political bodies develop laws that protect responders and hospital personnel from legal suit during the triage and care of mass-casualty survivors during a public health emergency. The State of Georgia recently passed legislation to protect first-responders and hospital personnel from civil or medical malpractice suits while they plan for, mitigate against, or respond to a public health emergency.[31,32]

Summary

Preparations for the 24-hour threat of a community HazMat exposure is a community responsibility for first-responders and the hospital. Policies, protocols, training, PPE, and decontamination systems should be developed and purchased to enable a safe community assessment and treatment for the victims.

Local industry depends upon the responder community to develop this response capacity. In the US, local hazardous materials transporters, manufacturers, and users are required to develop a disaster plan in the event of an accidental release. They are not required, however, to determine if the first-responders and the hospitals are capable of meeting the needs of the contaminated employees.

Preparations for a mass-casualty event as the result of an accidental hazardous materials release is a matter of community responsibility. A local hazard assessment will determine if there is a risk for a major release with harm to personnel or the community. The history of human injuries after accidental HazMat releases suggest that the chemicals more likely will result from an accident at a fixed site, such as an industrial user or manufacturer of hazardous chemicals, than a transportation event.[24] Many community HazMat events are the result of accidents on the road or from rail cars, which are more difficult to predict. A rail accident in Minot, North Dakota in 2002 caused hundreds of injuries and a death after the release of thousands of gallons of anhydrous ammonia.[34] The home also is a frequent source of exposure.

Preparations for a mass-casualty event related to a terrorist attack are a governmental responsibility. In the US, significant funds have been allocated by the federal government for local preparedness. Plans for these funds, however, have been criticized for a lack of focus and an inadequate threat assessment. Significant costs related to the procurement and sustainment of large tents and trailers designed for ambulatory decontamination can be reduced. The traditional approach to mass-casualty decontamination should be reassessed by federal, state, and local planners.

This new approach to mass decontamination meets the call to utilize resources based on multiple contingencies and existing assets. It does not require the creation or utilization of specialty teams for local response. Although specialized teams might be utilized for agent identification and assistance, and might be needed for extrication of the dead, existing local and regional resources should be able to meet the needs of the seriously ill and the ambulatory survivors.

Rapid, appropriate delivery of antidotes after a nerve agent or cyanide attack can save lives and decrease the need for extensive and prolonged hospitalization. It is unlikely, however, that antidotes will be of great benefit due to the time-sensitive need for the antidotes and the personal protection requirements for the responders. More than likely, those that survive to rescue will survive. Those that require the rapid utilization of antidotes likely will die due to delay in the availability of the antidotes unless they can be delivered within minutes by well-trained, first-responders dressed in appropriate PPE under the guidance of medical control. In some cases, antidotes may be beneficial to first-responders for self-care or pre-positioning for high-profile events.

Conclusions

First-responders, hospital personnel, emergency managers, public health professionals, elected officials, large employers, industry, hospital administrators, and hospital associations must work together to develop credible community plans to meet the threats of a chemical MCI, including a terrorist attack. It is feasible economically to meet the threat of a chemical attack. Utilization of a threat assessment that separates vapor from liquid chemical threats can enable local responders to effectively manage a chemical attack with mass casualties. Ensuring that hospitals have adequate resources and training to mount an effective decontamination response in a rapid manner is essential. After a mass-casualty incident with a large numbers of survivors, triage efforts to divert ambulatory patients from hospitals will enable the incident commander to offer appropriate care to all victims in a timely fashion. Adherence to government safety regulations is necessary to protect personnel from exposure to chemicals. Maintaining a communication system that allows for the timely flow of information greatly enhances the quality of coordinated care and mobilization of resources.

"The shortest and surest way of arriving at real knowledge is to unlearn the lessons we have been taught, to mount first principles, and to take nobody's word about them."
Henry St. John Bolingbroke, English Statesman (1658–1751)

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