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General Approach to Chemical Attack

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The risk of chemical attack is no longer confined to the battlefield. The rise of asymmetrical terrorist tactics, combined with the dual-use nature of technology and the proliferation of information, makes chemical terrorism a realistic threat for domestic first responders. In addition to conventional chemical warfare agents, the threat now includes the use of toxic industrial chemicals and materials that, as part of an industrial-based economy, are ubiquitous in much of developed society. Prevention, preparation, and response to such an attack requires consideration of myriad issues and integration across disciplines to ensure optimal use of limited resources and the development of best practices. Coordination of these efforts into a cogent emergency management program requires cooperation across communities, jurisdictions, regions, states, agencies, and industries, all of which will improve the capability to respond to all hazard challenges. This chapter focuses on the fundamentals of preparing for and responding to a chemical attack.

HISTORICAL PERSPECTIVE

Brief History

The history of chemical warfare is tragic and extends back millennia. An excellent summary of this topic can be found in the *Textbook of Military Medicine.*[1] The "modern era" of chemical warfare began during the events leading up to and surrounding World War I. Many of the agents developed during and between the World Wars, including chlorine gas, mustard gas, and cholinergic nerve agents, have unfortunately continued to play a prominent role in more recent conflicts including the Iran-Iraq War and the Syrian Civil War.[2–3] In the United States, the Chemical Warfare Service was established on June 28, 1918, as part of the National Army, with responsibilities for all chemical weapons research, defense, training, medical treatment, and production facilities. The offensive weapons program was officially terminated by signature to the United Nations (UN) Chemical Weapons Convention (CWC) on January 13, 1993, with Senate approval on April 24, 1997. The existing infrastructure was converted to a strictly passive defense program, with the U.S. military providing valuable input toward preparations for a chemical attack. This framework—combined with Hazardous Materials (HazMat) response work statutes from the Occupational Safety and Health Administration (OSHA) and the National Fire Protection Administration (NFPA) Guidelines governing fire and emergency services response—has served as the cornerstone of current U.S. doctrine for preparation, training, and response to chemical attacks in noncombat situations.[4,5]

The Chemical Weapons Convention

The CWC, formally titled the "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction," opened for signature on January 13, 1993, after 20 years of negotiation and entered into force on April 29, 1997. The CWC outlines prohibited use, production limits, compliance measures, and mandates to destroy stockpiles of specific chemical warfare agents. Furthermore, it established the Organization for the Prevention of Chemical Weapons (OPCW), located in The Hague, Netherlands, to serve as its operational arm, conducting verification activities, ensuring implementation of convention provisions, and providing a forum for consultation and cooperation.[6] As of December 2020, 193 UN member states have signed the CWC, and 98% of worldwide chemical weapons stockpiles declared by member states have been verified as destroyed.[7] However, the use of chemical agents including chlorine, sarin, and mustard gas during the ongoing Syrian civil war, including by the Assad regime against its own citizens, is a stark reminder of the progress that still needs to be made.[2]

Chemical Agents

The U.S. Department of Homeland Security (DHS) defines a "chemical attack" as "the spreading of toxic chemicals with the intent to do harm."[8] As such, a chemical attack requires a chemical compound capable of causing morbidity and mortality, produced in sufficient quantity, and combined with the necessary chemical and/or mechanical means for effective dispersal. By definition, these agents are controlled under the CWC. However, a chemical attack may also involve industrial compounds that are more readily available in larger quantities and are less tightly controlled. At least 125,000 compounds are designated as toxic industrial chemicals. These agents are generally defined as a chemical, excluding chemical warfare agents, that have an LCt50 (lethal concentration for 50% of a population exposed over a given time, *t*) less than 100,000 milligrams per minute per cubic meter in any mammalian species and are produced in quantities exceeding 30 tons annually at any one production facility. Of these, approximately 4600 are considered "critical," and almost 400 are "extremely hazardous."[9,10] For instance, methyl isocyanate is the toxic industrial chemical implicated in the Bhopal disaster, which occurred at the Union Carbide pesticide plant in Bhopal, India, in 1984. About 40 metric tons of methyl isocyanate, an intermediate in the production of the pesticide carbaryl, were unintentionally released into the surrounding environment, resulting in the deaths of more than 3000 people within 3 days from pulmonary edema.[11]

Chemical agents can be dispersed in various forms (e.g., vapor, aerosol, smoke, liquid, solid) depending on the characteristics of the agent and the intended exposure route. Most large-scale hazardous chemical incidents (intentional or unintentional) occur through inhalation exposure, but other routes, such as dermal contact or ingestion of contaminated food or water, could result in substantial casualties. Individual agents, their characteristics, and treatment are covered later in this section.

CURRENT PRACTICE

In the United States 14,000–22,000 HazMat-classified events occur yearly, although emergency medical service (EMS) activation is rare, and the majority of incidents involve only 1 to 2 patients. This means prehospital familiarity with CBRN (chemical, biological, radiological, nuclear) events may be lacking, particularly if a large-scale event occurs.[12–13] Chemical attacks may occur suddenly and unexpectedly, with only local and regional response capabilities available to manage the early phases of the incident. A large-scale intentional chemical attack will also require state and federal resources. Each community's preparedness efforts should begin with a thorough understanding of all available resources and methods to rapidly mobilize them if needed. Contemporary tactics, techniques, and procedures (TTP) for the emergent management of chemical attacks have evolved from a combination of response practices from emergency services, HazMat response, and military chemical warfare defense doctrine.

Various panels have developed consensus "best practices" reports and documents, many compiled and available at the Homeland Defense Information Analysis Center (HDIAC).[14] The National Medical Response Teams (NMRT), part of the National Disaster Medical System (NDMS) under the Department of Health and Human Services (DHHS), represent civilian teams charged with responding to mass casualty incidents (MCI), providing decontamination, medical triage, and treatment. These MCIs may include chemical, biological, radiological, nuclear, and explosive (CBRNE) attacks. In 1996, the military established the U.S. Marine Corps (USMC) Chemical Biological Incident Response Force (CBIRF) to respond to mass casualty CBRNE attacks.[15] Additionally, the Department of Defense (DoD) continues to build its National Guard CBRNE Consequence Management Enterprise, which includes 10 Homeland Response Forces, a Defense CBRNE Response Force (DCRF), two command and control consequence management response elements (C2CRE), 57 Weapons of Mass Destruction Civil Support Teams (WMD-CST), and CBRNE-enhanced Response Force Packages (CERFP) that were expanded in 2006 to 17 teams. Aligned and distributed along the 10 nationwide Federal Emergency Management Agency (FEMA) regions, the teams are located for timely response to major population centers with expected response times of 6 to 12 hours. These teams represent model constructs for concepts of operations for their particular missions.[15]

DOCTRINE AND POLICY

National Incident Management System

Presidential Policy Directive-8 (PPD-8) for National Preparedness[16] establishes and defines the National Preparedness Goal and National Preparedness System as a network of planning frameworks integrating incident management across critical sectors, jurisdictions, and response organizations. PPD-8 builds on foundations set by Homeland Security Presidential Directive-5 (HSPD-5) defining the National Incident Management System (NIMS) as the comprehensive approach in preventing, preparing for, mitigating, responding to, and recovering from domestic incidents. The Incident Command System (ICS) and Unified Command System (UCS) are used to develop a common operating picture accessible across jurisdictions and functional agencies.[17] The approach is to be used at federal, state, local, and tribal government municipalities.

Emergency Management Programs

HSPD-5 establishes and defines the five phases of emergency management as prevention, preparedness, mitigation, response, and recovery, around which emergency management programs (EMPs) are built. EMPs use an "all hazards" approach to disasters with an overarching plan and specific strategies for various incident types, including chemical disasters. For incident management response, the Hospital Incident Command System (HICS) has become the standard used by many hospitals, and the HICS organization makes program management materials readily available online.[18] For additional information on HICS and EMPs, please reference Chapter 5: The Role of Hospitals in Disasters.

For chemical attacks, critical actions in preincident planning phases include (1) identifying first responders/first receivers for triage, treatment, and decontamination teams; (2) establishing appropriate training, exercise, and evaluation programs; (3) developing respiratory protection and supply programs; (4) selecting key suppliers and locations for chemical antidotes; and (5) drafting and testing life-cycle management programs, communication plans, operational and evacuation procedures and policies, shelter-in-place procedures, and warning and notification procedures.

The Hazard Vulnerability Analysis (HVA) assists in determining personal protective equipment (PPE) requirements, potential emergency demands on a system, weaknesses and deficits anticipated in critical incidents and identifying other specific planning requirements. The HVA is done in conjunction with local municipal efforts. Community planning for hospitals includes coordinating with all other regional hospitals on all aspects of EMPs, including communications, mutual aid agreements, specialized treatments, alternate care facilities, cross credentialing, information management, supplies and logistics, and training exercises.

Finally, the critical step may be networking, communication, and information management links that are established during the preincident phases. Such relationships allow for rapid reorganization or self-organization of response systems under catastrophic duress, but they must be established before the incident to be effective. Hospitals should craft their HVA in conjunction with their local emergency preparedness committees. In brief, although having a plan is essential, the most valuable step is oftentimes the planning process.

CURRENT STANDARDS AND GUIDELINES

The current operating standards applicable to chemical attack response present challenges on several fronts. For example, statutes developed for the workplace or the battlefield may be suboptimal for an urban MCI response. The need for multidisciplinary expertise in developing EMPs also requires that various regulatory agencies and professional societies collaborate in establishing pragmatic statutes and guidelines. Challenges include developing standards around so many unknown entities within the response requirements and the limited real-world experience of large-scale incidents. A review of the various agencies with statutory authority demonstrates the importance of coordination and cooperation, and further details are provided elsewhere in this text.

FEMA now serves as the central integrating agency for incident management at the federal level.[19] It plays a huge role in nearly all aspects of emergency management, including coordinating interagency planning, national training standards, best practices, incident management, grant programs, and lessons learned from collection and analysis.[20] It maintains the Lessons Learned Information Sharing (LLIS) portal,[21] which includes the Responder Knowledge Base (RKB) and the Authorized Equipment List (AEL).[22]

OSHA,[23] within the Department of Labor, serves as an advocate for employee safety and health by developing standards for workers and workplaces. These principles include establishing safe exposure levels to hazardous chemicals during routine work and for short-term and emergency exposure. OSHA also works with the National Institute of Occupational Safety and Health (NIOSH), other federal agencies, and private industry to develop standards for general emergency planning,[24] Hazardous Waste Operations and Emergency Response (HAZWOPER) standards,[25] and PPE[26] for emergency response personnel. More specific information is available in the OSHA Technical Manual.[27]

The Code of Federal Regulations (CFR) serves as the basis for first responder safety in emergency response to chemical attack. However, OSHA recognizes that statutory code written for emergency responders at an incident site may be too restrictive for hospital-based "first receivers"[28] or those health care workers who receive contaminated victims at treatment facilities. Accordingly, OSHA promulgated guidelines to provide hospitals with expert consensus regarding safe response practices.[29] In addition, incident commanders (ICs) may use their expertise and experience to make a risk assessment that allows responders at hospitals or at an incident site working under their supervision to deviate from standards to save lives.[30]

The NFPA[31] develops guides and recommends practices, codes, and standards for the protection of firefighters and emergency responders. Standards are enforced through OSHA declaration. For example, NFPA defines PPE levels 1 to 4 (e.g., level 1 being vapor-protective for hazardous chemical emergencies; level 2 being liquid splash-protective for hazardous chemical emergencies; level 3 being liquid splash-protective for nonemergency, nonflammable hazardous chemicals; and level 4 being standard work clothes).[32] These levels generally correspond to OSHA levels A to D, respectively. NFPA also has several guidelines regarding competencies for first responders responding to HazMat events.[33–34] As background, NFPA generates their own policies as a private, nongovernmental entity for national firefighter standards that are then adopted by OSHA as federal standards. Meanwhile, OSHA has their own nonfirefighter regulations. In the "hot zone," both NFPA and OSHA standards are used depending on which agency the responder is working under (fire and emergency services, HazMat, EPA, etc.). For the most part, manufacturers develop PPE that meets both criteria levels.

NIOSH, a division of the Centers for Disease Control and Prevention (CDC), seeks to prevent work-related illness and injury by ensuring the development, certification, deployment, and use of PPE and fully integrated, intelligent ensembles. Although NIOSH establishes standards, it does not have enforcement authority as it is not a regulatory agency, unlike OSHA.[35] The National Personal Protective Technology Laboratory at the NIOSH partners with NFPA, OSHA, DoD, the National Institute of Standards and Technology (NIST), and the National Institute of Justice (NIJ) in the development of standards for CBRN respirators and their certification. All respirators used for response in a chemical attack must meet NIOSH certification.[36]

The Office of Law Enforcement Standards (OLES) at NIST, part of the NIJ, works with various agencies and partners to establish objective performance standards and equipment testing programs for critical equipment. CBRNE standards development falls under the "Critical Incident Technologies" program area. Applying technical expertise and "gold standard" laboratory capabilities, OLES works with its partners to recognize technical issues, develop standard testing protocols, identify testing labs, and establish standards for such things as communications interfaces for the first responder in protective equipment, tracking first responders, and networking sensors. The standards are then issued through the appropriate agency with statutory authority, such as NIOSH, the Environmental Protection Agency (EPA), OSHA, FEMA, DoD, or the Department of Homeland Security (DHS). OLES also partners with the Interagency Board for Standardization of Equipment and Interoperability (IAB). PPE guidelines carry through the U.S. Department of Justice Law Enforcement and Corrections Standards and Testing Program.[37,38]

The IAB, formed in 1998 through a partnership with DoD and the Federal Bureau of Investigation (FBI), ensures standardization and interoperability throughout the response community in preparing for and responding to weapons of mass destruction (WMD) incidents. Although it does not create statutes, the IAB has an expanded stakeholder list of federal and local partners that includes statutory agencies. It reorganized in 2008, and its six subgroups, all with local and federal representation, work to develop, maintain, and update a national standardized equipment list (SEL). This SEL is maintained on the IAB website.[39]

Research, Development, and Support

In addition to many excellent academic research centers, the Technical Support Working Group (TSWG) conducts the U.S. interagency research and development program for combating terrorism, coordinates research and development requirements, disseminates technology information transfer, and influences basic and applied research. The CBRN Countermeasure Subgroup focuses on chemical incident response issues.[40] Supported by the DoD's Irregular Warfare Technical Support Directorate, the TSWG has broad representation from federal agencies and has international participation.

Other Departments and Agencies

Specific roles of federal agencies and departments are covered elsewhere in this textbook; however, some specific agencies merit mention here. The DHHS has several entities with relevance for chemical attack. The National Library of Medicine (NLM) provides ready, useful resources for information on chemicals.[41] Their online resource, Chemical Hazards Emergency Medical Management (CHEMM), represents a valuable repository of pertinent aspects of medical response to chemical incidents.[42] They use leading-edge technology, including Wireless Information System for Emergency Responders (WISER), to make information portable and accessible.[43]

The Agency for Toxic Substances and Disease Registry (ATSDR), an agency of the DHHS, serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and disease related to toxic substances. The ATSDR is directed by congressional mandate to perform specific functions concerning the effect on public health of hazardous substances on the environment. These functions include public health assessments of waste sites, health consultations concerning specific hazardous substances, health surveillance and registries, response to emergency releases of hazardous substances, applied research in support of public health assessments, information development and dissemination, and education and training concerning hazardous substances. ATSDR and the EPA publish toxicological profiles for hazardous substances and include them on the Substance Priority List (SPL), which uses the National Priority List (NPL) of sites with known or threatened releases of hazardous substances and ranks these based on frequency of occurrence at the sites, toxicity, and potential for human exposure. The profiles for nearly all of the 275 toxic substances on the SPL are available on the ATSDR website.[44] The DHHS is also home to the Public Health Emergency Medical Countermeasures Enterprise (PHEMCE), which coordinates with federal efforts to enhance preparedness for CBRN threats.[45]

The DoD is covered in more detail in other chapters of this textbook; however, several agencies play significant roles in preparing for and responding to chemical attacks. The Combat Capabilities Development Command (CCDC), formerly known as the Research Development & Engineering Command (RDECOM), is the research and development arm (R&D) of the U.S. Army's Chemical Corps. CCDC, with the Edgewood Chemical Biological Center (ECBC), applies this R&D effort to develop concepts of operations, training programs, collaborating across the chemical-biological response paradigm, and providing publications addressing significant, challenging issues in chemical incident response.[46] CCDC also serves as the testing facility for NIOSH, whereby it performs official testing of mask/filter combinations against chemical weapons for CBRN certification.

The Army Forces Command 20th Support Command (CBRNE), formerly known as Guardian Brigade, represents an expert team specializing in responding to emergency aspects of chemical incidents;[47] although robust, CBRNE response capability now extends to many DoD units around the nation. The USMC CBIRF is a rapid response, antiterrorism unit based in Indian Head, Maryland. The CBIRF serves as a model for CBRNE response teams around the world. CBIRF works closely with partners at all levels of government and private industry to develop, evaluate, and validate best practice TTPs for "all hazards" emergency management planning, improvement of response equipment, and development of advanced training techniques related to CBRNE.[48] The U.S. Army Medical Research Institute for Chemical Defense (USAMRICD) provides the nation's primary medical laboratories charged with identifying chemical weapons threats and developing medical countermeasures, including antidotes, barrier creams, decontamination solutions, and chemoprophylaxis. The training arm of the Institute for Chemical Defense develops and provides the chemical portion of the "gold standard" Medical Management of Chemical/Biological Casualties and the Field Management of Chemical and Biological Casualties courses.[49]

The DHS also contributes to Chemical Defense through several offices. The Office of Science and Technology coordinates research and development and supports the Chemical Security Analysis Center (CSAC), which among other things, conducts the Chemical Terrorism Risk Assessment.[50] The DHS Office of Health Affairs Chemical Defense Program also works with state, local, and private-sector partners and has completed National Planning Guidance for Communities for Patient Decontamination in a Mass Chemical Exposure Incident.[51]

THE RESPONSE

A chemical attack will likely occur abruptly and unexpectedly, creating large numbers of casualties. From past incidents, it is expected that accurate information about the cause and extent of the event will only become clear over time. Incident command will be forced to make critical decisions about all phases of the response during a period of uncertainty and limited information. The scene perimeter will likely only be secured after many potentially contaminated victims leave the scene and even enter the health care system. What's more, specialized response teams, mutual aid, and other resources require time to mobilize. Therefore the initial response lies on the shoulders of the local response community. Local resources are likely to become overwhelmed, and additional resources will be necessary to augment the initial response capabilities. Although some chemicals exert their effects within seconds of exposure, the duration of response extends much longer. In fact, delayed and multipeaked exposure and symptom onset patterns may be caused by several factors. These include chemical and physical properties of the agent(s) used, intentionally delayed and malfunctioning dispersal devises, secondary dispersal devises, weather patterns, varied medical comorbidities among victims, incomplete or incorrect medical treatment, and the inadvertent escape of contaminated victims outside of the quarantine zone. Sublethal doses combined with underlying medical conditions, extremes of age, or coincident trauma or panic can lead to significantly compromised patients. Planning and preparedness assumptions should account for both immediate and ongoing response components.

During the Iran-Iraq War of the 1980s, Iran suffered several chemical warfare mass casualty attacks using nerve agents, vesicants, or a combination of the two (sometimes in combination with conventional artillery attacks). The Iranian health system responded to these MCIs, adjusting strategies and procedures over time by providing medical care closer to the incident site, eventually deploying mobile medical teams to provide on-scene care. Lessons learned from published reports include the need to treat early and far forward to confer maximal patient benefit, for integrated systems of care, and for a rapid response to enable supportive and antidotal therapy and recovery for mild, uncomplicated casualties.[52]

Several factors make it difficult to predict response time requirements. Toxicity and lethality data of specific agents are derived from animal models and are not easily translatable to humans. Pharmacokinetics and agent efficacy are likely affected by extremes of age, confounding medical problems, and concomitant trauma, with unknown effects on the course of poisoning and greater potential for effects of sublethal exposures. What is more, environmental factors will have a major influence on dermal and inhalational bioavailability, rate of absorption, and duration of agent persistence in the local setting. These factors include temperature, wind, humidity, precipitation, location size and ventilation (indoor sites), and topography (outdoor sites). The additional time and effort necessitated by PPE and decontamination protocols adds another dimension of complexity. Finally, the management of large-scale MCI is poorly studied, which adds to the unpredictability of chemical attack effects and response. The critical point is that response time requirements and treatment outcomes are not known and are unique to each event; they may be affected by a multitude of factors, and they may be extended in duration.

INITIAL ACTIONS

Recognizing an Attack

Execution of a chemical attack may be overt (an explosive device), covert (an aerosolized dispersal device), or somewhere in between. Crude explosive dissemination devices typically use a third of the explosive component compared with conventional explosive devices to minimize consumption of the agent and maximize spread. Consequently, improvised explosive devices (IEDs) that seem to have more smoke than blast or fire might indicate a chemical dispersal device. Vapor clouds, smoke without fires or with color, or more sophisticated spray devices or aerosolizers in unusual places may indicate an attack. Clinically, multiple victims with similar symptom patterns (e.g., the bronchospasm, bradycardia, and hypersecretory state seen in cholinergic nerve agent toxicity) may indicate a chemical attack. The presence of dead or symptomatic animals should also raise suspicion of a chemical attack. Critically, any chemical attack is both a HazMat incident and a crime scene. Responders should consider crime scene preservation when practical.

Establishing Scene Safety

Initial actions on scene should include maintaining a high index of suspicion for the presence of a toxic material and additional, secondary explosive or dispersal devices. First on scene and incident command should establish zones of operation. The "cold zone," or low risk area of operations, should be established upwind and upgrade from the contaminated "hot zone." A "warm zone," or contamination-reduction corridor, defines the area adjacent to the hot zone that is initially uncontaminated, but where decontamination will occur. Ambulatory victims can be directed toward safe haven gathering points in the cold zone to await further directions as the response ensues.

RESPONSE CAPABILITIES

Effective response to the chemical attack MCI is best approached by defining the functional capabilities for response requirements at the incident site. These capabilities include both human (e.g., trained

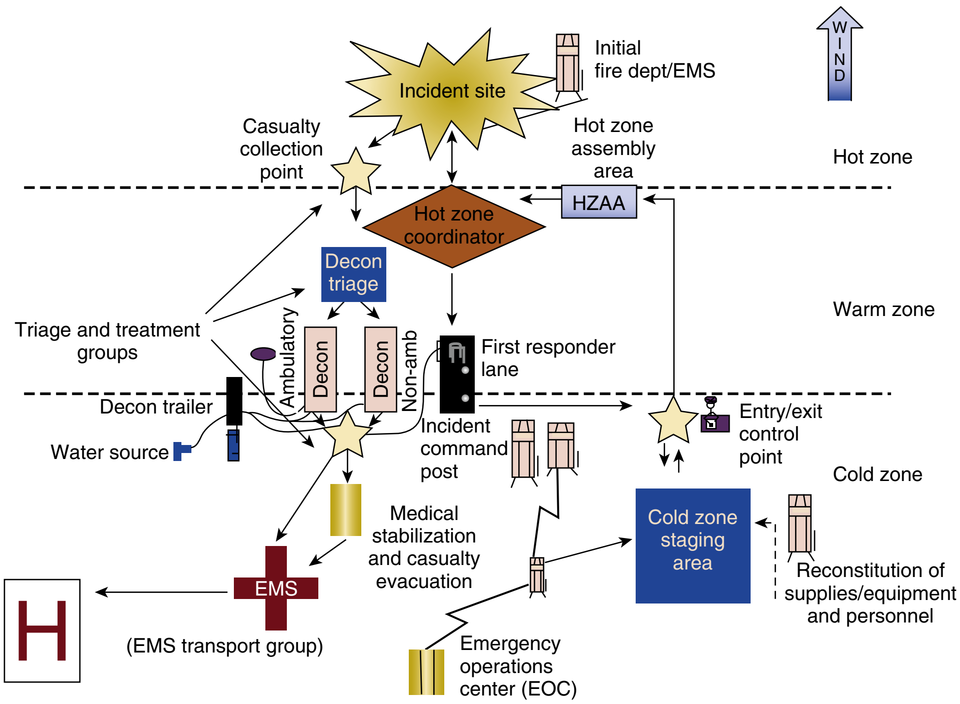

Fig. 81.1 Typical Incident Site Response Scheme.

responders) and physical (e.g., supplies and infrastructure) capital. These resources will vary in quantity and capability, depending on the response requirements and driven by factors including the incident, local availability, and other constraints as interpreted by the IC. The same functional capabilities also define response resources required at secondary sites, such as hospitals or alternate treatment sites, where first receivers treat victims who were not evaluated or decontaminated at the incident site. Fig. 81.1 demonstrates a typical incident site response scheme.

Command and Control

The ICS/UCS provides a standard framework for responding to a chemical attack. The IC, located at the incident command post, establishes the incident action plan following general incident action guides. The NIMS provides guidance on these activities. The IC is responsible for crisis action planning, accountable for the safety and actions of all response personnel, and liable for actions during the response. As per the NIMS, the ICS creates a UCS as the national standard response structure. Under the ICS/UCS system, the "best qualified" person initially on scene assumes the role of IC. Transition to a UCS occurs as soon as reasonably achievable. ICS training and job aids listing such things as organizational charts, roles, responsibilities, meetings, response action guides, and sample forms are available from various sources and provide excellent guidance for developing response plans to chemical attacks.[42,44–45] Handheld information technology emergency response tools are also commercially available.[53–55]

As in all incidents, the size and effect of the incident drive the staffing of positions in the ICS, with roles and responsibilities becoming more specific as the size increases. The IC establishes a command post in a safe place near the incident site, analyzes the incident, and incorporates detection and reconnaissance data, plume modeling, and weather effects as available, and then develops and implements the incident action plan and evaluates the progress. Ongoing hazard and risk assessments allow the IC to determine the threats, estimate the potential course and harm to develop strategic goals and tactical objectives, determine the required protective measures and PPE levels, and assign team tasking goals and missions to the various response squads, teams, or units. The risk assessment also allows the IC to use experience and expertise to deviate from statutory regulations, if necessary. Leaders are expected to coordinate and integrate their teams into the IC's incident action plan.

Because state and federal response infrastructure may be necessary to augment the local response capabilities, the community's plan should clearly address how each will be notified or requested and the expected response times and roles in the incident command structure. Every opportunity to build relationships with these response capabilities, such as training exercises, will prove invaluable during a real crisis.

Reconnaissance/Hazard Detection and Identification

Reconnaissance teams are responsible for describing the environment of the hot zone and helping the IC define safe operating parameters for the worksite. These "recon" teams provide critical information, such as oxygen levels, presence of explosive gases, chemical agents, radioactivity, mechanical hazards, and structural integrity of buildings. Further, these teams report casualty numbers, locations, and conditions to guide IC management of the incident. Typically, the recon team initially works in OSHA level A (NFPA level 1) or level B (NFPA level 2) suits, because the environment is "undefined," and chemical levels are assumed to be an immediate danger to life and health (IDLH).

Various detection/identification technologies are available and are beyond the scope of this chapter. Research is continuously ongoing to improve the ability to detect and identify more chemicals more quickly and reliably. Information provided by the recon team allows the IC to determine the appropriate level of PPE for the other elements of the response team. Because it is difficult to rapidly and portably identify qualitative and quantitative levels of many chemicals, response teams will often default to using higher levels of PPE.

Chemical identification is a critical element to good decision making during a response. Just as important as the recognition of the compounds involved is the dissemination of this information to key elements of the response system (e.g., law enforcement, EMS, hospitals, public health, medical examiners, and environmental responders). During the early phases of an emergency response, missing information, misinformation, and the lack of exact chemical identification will challenge the IC's ability to make critical decisions. Although the exact chemical name is desirable, it may not be absolutely essential information. For example, early in the response, managing a suspected class of agent is better than managing a complete unknown. As the response unfolds over time, responders may identify the specific chemical and the response can be focused. Clinical recognition of *toxidromes,* or clinical constellations of signs and symptoms ascribed to a specific class of chemical compounds, can complement detector technology and help identify a potential chemical class. This early information may be sufficient to give medical staff the direction to administer specific antidotal countermeasures during a crucial window of opportunity to save lives. A specific example of this would be rapid recognition of the cholinergic toxidrome precipitated by an organophosphate nerve agent such as sarin and early administration of atropine and pralidoxime via predistributed autoinjectors.[56] Indeed, when Russian agents allegedly attempted to assassinate Sergei Skripal and his daughter with an organophosphate "Novichok" nerve agent in 2018 in Salisbury, England, at least six individuals were exposed with only one death, illustrating the value of rapid response.[57]

Casualty Extraction

Casualty extraction is likely the most emotionally and physically challenging of the functional elements of response, because it requires the ability to make life-and-death triage decisions in chaotic environments while under demanding physical exertion and working in restrictive, high-level PPE. Victims who cannot ambulate out of a toxic environment must be carried out to optimize outcome. Current protocols are not evidence-based or optimized for survivability. Heat stress and heat exhaustion collapse are significant problems for the extraction teams, particularly on warm or sunny days. Furthermore, efforts to extricate casualties may dislodge rescuers' PPE and expose them to the chemical agent. The IC should limit work cycles to 30 minutes or less with adequate preprescribed rehabilitation time in between work cycles.

Casualty extraction operations should include designated team members as "victim assist teams." The victim assist teams prevent ambulatory victims from wandering outside of established control zones and decontamination corridors to limit cross contamination of clean areas and to mitigate interference with decontamination set up. Such teams then assist with patient flow and transport, clinical care, and crowd control.

Medical Triage, Treatment, and Transport

The medical unit of the logistics section of the command post oversees the medical triage, treatment, and transport of patients at the incident site, interfacing with other aspects of the ICS/UCS in carrying out the incident action plan. Depending on the size of the response, there may be branches overseeing triage and treatment or transportation groups, divisions, or task forces.

Most existing chemical response MCI triage systems lack evidence to support their efficacy. Further, little guidance exists to define crisis standards of care in the chemical attack response environment.[58,59] Triage systems employing algorithms that consider medical resources, transport times, and predicted survivability have been proposed to optimize outcomes.[47] Although these are described in trauma databases, it is not clear whether the same criteria used for triage prioritization would correlate to survivability for a chemical incident.

Triage and treatment teams are best placed at naturally occurring "bottlenecks" from the hot zone through the contamination-reduction corridor (i.e., warm zone) to a medical stabilization area in the cold zone. Depending on distances and specifics of the incident site, a casualty collection point (CCP) might be established at the border between the hot and warm zones, where extractors can transfer victims to initial care in a relatively less-contaminated environment. A CCP allows for early access to medical attention, including initial triage and treatment, and it shortens the length of the extraction cycle. Although it may be beneficial to deploy dedicated medical personnel into the hot zone to provide limited triage, medical direction, and treatment, there exists little evidence to support this practice as being the best use of limited medical resources. That said, for agents to which antidotal therapy exists, early administration of antidotes by appropriately trained first responders working in the hot zone is likely beneficial. This is because of the time-dependent toxicity of many chemical agents, such as the organophosphates that become refractory to pralidoxime therapy as they age; soman, for example, ages in only 2 minutes, whereas sarin takes 3 to 4 hours.[60]

Medical treatment teams placed on both ends of the decontamination process (in the warm zone and the cold zone) will facilitate better prioritization of patients moving through decontamination, provide medical oversight for patients during the formal decontamination process, and facilitate retriage and treatment in preparation for transfer to care facilities. Little more than simple circulatory support, airway management, and occasional antidotal treatment can be accomplished in a medical setting as far forward as the warm zone. That said, these maneuvers can have meaningful effect on morbidity and mortality for individual patients (although it is unknown how time and resources allocated in this way may affect overall casualty numbers). To note, as many chemical agents have significant and progressive respiratory and ventilatory effects, airway management proximal to the incident site should be a primary area of focus for planning and preparation for a chemical attack. What is more, depending on the chemical agent, antidote administration should be accomplished along the entire medical treatment corridor and is part of the lifesaving interventions aspect in the CDC backed sort, assess, lifesaving interventions, treatment/transport (SALT) mass casualty triage scheme.[61] Regulatory authorization and specialized training for antidote administration by unlicensed medical responders must be considered. These arrangements should be established during the preparation phase of an emergency management program.

PPE requirements for medical providers in the warm zone are an area of interest to OSHA, although the IC determines the level required. For a response conducted remotely from the incident site, such as at a hospital or alternate care facility, OSHA has perpetuated the specific first-receiver guidelines mentioned previously.

Decontamination

Removal of clothing is known to eliminate up to 80% to 90% of contamination. As these events are also often crime scenes, clothing should be placed in labeled, sealed individual bags. Afterward, current best practices rely on physical removal of agents using soap and large volumes of water. Use of 0.5% bleach solution has fallen out of favor. Several good consensus standards have been published.[62–65] There is evidence, however, to suggest these water-based techniques, if not performed immediately after exposure, may not be effective and may even cause more harm.[66] Others argue for a more rational approach that considers high molecular weight solutions optimized for specific agent characteristics, including solubilities.[67] A comprehensive review of decontamination guidelines conducted by a joint effort by the DHS Office of Health Affairs and the DHHS PHEMCE resulted in the "Patient Decontamination in a Mass Chemical Exposure Incident: National Planning Guidance for Communities." This multiyear effort included broad participation of stakeholders in government, the private sector, and the general public, and it provides national planning guidance for communities on patient decontamination in mass chemical exposure incidents.[68]

Mass casualties requiring decontamination present major challenges to the resources, personnel, and efficiency of a community response. After a chemical attack, potentially contaminated patients may be injured and remain on scene, unable to extricate themselves, or they may be ambulatory and return to their daily lives or self-present to the hospital. Proper decontamination decreases exposure dose by diluting or removing chemicals, thereby preventing additional absorption and reducing the spread of chemicals that could jeopardize critical human and physical resources. A tiered approach facilitates rapid contamination reduction for a large number of people and may decrease chemical exposure. This strategy begins by quickly instructing exposed groups how to perform self-care, followed by rapid gross decontamination and subsequent technical decontamination. Each step along the way requires resource capabilities that are more intense.

For ambulatory patients, most systems essentially represent mass shower sequences through tents for set periods of time, with a range of shower times depending on various factors. Although disrobing drastically reduces contamination, some care to the process must be applied to prevent cross contamination or inhalation. Decontamination of nonambulatory patients is time and personnel intensive. Even the most comprehensive systems and experienced teams do not provide adequate throughput for true MCI. Roller systems that allow easier, rapid movement of patients through a car wash-like system take more than 2 to 5 minutes per patient. Set-up times for different teams and systems vary, and if not prepositioned, provide additional challenges resulting from large physical footprints and time to set up. In addition, mass casualty decontamination requires a large, reliable water source, and is largely immobile. A further consideration is that decontamination will increase the risk of hypothermia among patients both via clothing removal and washing.

There are several critical issues in the decontamination process. First, it requires at least three separate lanes: one for ambulatory patients, one for nonambulatory patients, and one for responders. Each group will have different decontamination requirements and priorities. The responder lane becomes especially time-critical for responders on supplied air who will usually be near the end of their air supply during the decontamination process. Cutting clothes with "J knives" versus scissors may enhance the throughput capability and avoid hand fatigue. Second, controlling water temperature during the decontamination process can be a challenge given portability, sourcing, and volume requirements. Third, decontamination lanes are typically staffed with nonmedical personnel, so medical oversight during the decontamination process needs to be provided with clear protocols for alerting medical providers of any medical issues in patients during the decontamination process. Finally, the environment in decontamination systems can become very hot and humid. The effect on personnel and filter performance must be considered. Neutralizing solutions such as Reactive Skin Decontaminant Lotion (RSDL) are commercially available and may offer more favorable decontamination performance, particularly in the case of lipophilic agents, including some organophosphates and vesicants.[57,69]

Scene Security/Explosives Ordnance Disposal

Scene security is critical for maintaining order and personnel accountability, controlling and maintaining zone boundaries for contaminated areas and scene perimeters, directing traffic flow, and preventing secondary attacks that might jeopardize the initial response. Trained law enforcement personnel should assist with maintaining the integrity of the operational decontamination zones. Explosives Ordnance Disposal (EOD) teams, when available, should provide a sweep for secondary devices such as IEDs and chemical dispersal devises that might target responders.

Supplies and Logistics

Special attention to logistics is needed to ensure that resources are properly distributed. It is crucial that response teams identify and carry items they will need in a given response so as to not create a logistical burden when they present to an incident. Teams should be able to provide accurate estimates of the quantity of their resources, identify sources for replacement supplies, and outline any critical support requirements that the unit might have. For logistical support of chemical attacks, there are several programs worth mentioning in addition to the Strategic National Stockpile (SNS) that can provide critical supplies to a response in a more reasonable time frame.

The CHEMPACK Program, part of the SNS Program, provides forward placement of supplies and equipment specifically needed in the event of a chemical attack so that state and local governments can improve their response times. Planning with the prehospital, hospital, poison control center, and public health communities can activate this resource, ensuring that it will arrive during the crucial window of opportunity to save lives. The CHEMPACK Program prepositions medical countermeasures, including those against organophosphate nerve agents, with two types of containers: one geared toward EMS, which contains 85% autoinjectors with ∼450 casualty capacity, and another geared toward hospitals, which contains 85% multidose vials with a 1000 casualty capacity.[70] Local preparedness activities should include training first responders and first receivers on how to recognize the clinical manifestations of poisoning, outline methods to request and mobilize these medical resources, and ensure the availability of dosing guidance for providers. Poison centers and medical toxicologists are valuable coordination points and subject matter experts for assisting with planning and response to incidents requiring the CHEMPACK. In the United States, 55 regional poison control centers are available at all times to provide management guidelines via a nationally available hotline (1-800-222-1222).

The Emergency Management Strategic Health care Group, under the Veterans Health Administration (VHA) of the Department of Veterans Affairs (VA), addresses emergency management functions for the VHA, including medical support to the DoD, NDMS, and the National Response Plan as needed. VA Medical Centers maintain caches with products to respond to CBRNE incidents for treating veterans, VA staff, and other individuals seeking treatment at a VA facility.

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Failure of integration and coordination: At the federal level, integration of emergency management response and homeland security is now the responsibility of the DHS, with the NIMS Integration Center established to oversee the process. It is incumbent on responders and managers at every level of the preparedness and response effort to ensure understanding of systems architecture, statutes, procedures, roles and responsibilities that affect them, and their integration into their emergency management program as appropriate and needed. Use and integration of information management tools is another area undergoing rapid development, and it should be encouraged with development of standards. Cooperation and compromise are necessary as requirements are identified and capabilities developed.

Failure to participate in a lessons learned process: LLIS[71] is designed to capture insights from various levels of government response and share the information appropriately with emergency response personnel and

DHS officials. Active participation in a lessons learned program is one of the professional responsibilities of emergency response personnel. Lessons learned come not only from actual response experiences but also from standard training, mock exercises, and ensuring feedback loops in evolving and improving TTPs.

Emerging Threats

As a parting consideration, it is vital to keep in mind that many of the traditional chemical warfare agents for which we train are decades old. With the progress of technology and science, further development of chemical weapons does not require the resources of a government-sponsored program. Many toxic industrial chemicals are more easily accessible than are traditional chemical warfare agents, and many are significantly toxic. These nontraditional chemical weapons may be desirable for those with bad intent. In addition, we cannot predict what novel agents may be developed or what their effects will be. As we look toward the future, we must plan for the worst and prepare for the unpredictable, with a specific focus on interagency communication, planning, training, and critical, creative thinking.

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