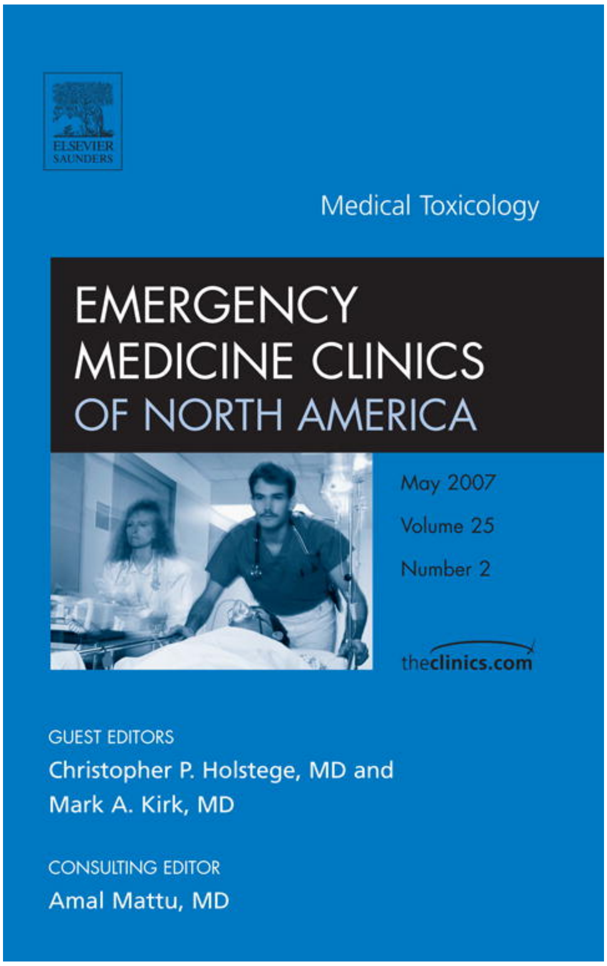

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Bringing Order Out of Chaos: Effective Strategies for Medical Response to Mass Chemical Exposure

Mark A. Kirk, MD[a,*], Michael L. Deaton, PhD[b]

[a]*Blue Ridge Poison Center, Division of Medical Toxicology, Department of Emergency Medicine, University of Virginia, P.O. Box 800744, Charlottesville, VA 22908-0774, USA*
[b]*Integrated Science and Technology, MSC 4102, James Madison University, Harrisonburg, VA 22807, USA*

An accident releasing hazardous chemicals or a deliberate chemical terrorism attack will create chaos and confusion that complicates the emergency response. Time is of the essence when administering treatment to the victims of hazardous chemical emergencies. Clinicians are challenged to urgently treat patients needing care, even before a chemical is confirmed.

Every day in the emergency department (ED), physicians routinely diagnose and simultaneously treat life-threatening conditions based on the best information available at the moment. Most often, basic clinical information such as physical findings and a few rapid point-of-care diagnostic tests provide sufficient information to empirically treat a critically ill patient. As time passes, the patient's condition is more clearly defined because additional information becomes available. Hazardous chemical emergencies, especially those caused by highly toxic chemical threat agents[1], such as nerve agents and cyanide, must be handled in the same way if health care providers are to save lives from the potent toxic effects. Hence, in the face of a chemical attack or accident, the medical response must be quick to recognize specific conditions that need urgent medical interventions.

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* Corresponding author.
E-mail address: mak4z@virginia.edu (M.A. Kirk).

[1] Chemical threat agents are toxic chemicals that could be used in a terrorist attack against civilians, or chemicals that could be released at toxic levels by accident or natural disaster. This is a term used by federal and Department of Defense agencies such as United States Army Medical Institute of Chemical Defense (USAMICD), Center for Disease Control (CDC), National Institute of Health (NIH), and Department of Homeland Security (DHS).

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Coupling basic toxicology concepts to a thorough understanding of the nature of hazardous chemical accidents can provide a framework for an effective emergency response strategy.

The chaos and confusion: anticipating the "most likely" challenges

The consequences of hazardous chemical accidents and chemical terrorism attacks are chaos, confusion, and seeming unpredictability [1–6]. How can those responding to the scene or awaiting the arrival of victims at the hospital gain a sense of control? Everyone involved can hope it will not happen in their locale, and hope, if it does, that the "all-hazards" plan will suffice.

Being proactive by anticipating the "most likely" challenges, and preparing for them may provide some sense of control. However, each incident is unique and it is impossible to be prepared for every challenge that may arise during the response. Nonetheless, common themes become evident when incidents are evaluated using evidence-based disaster planning [7]. By analyzing past events, challenges can be identified that are likely to occur in any emergency response. Therefore, one of the first steps toward preparedness requires learning from the past to attempt to answer two questions: (1) what are the most common challenges likely to occur? and (2) how are people likely to behave during these events?

Despite the observations from evidence-based disaster research and reports of recurring challenges during incidents, the literature shows that many lessons are "learned" over and over [7–9]. In addition, an often-overlooked factor in planning is anticipating and managing the behaviors of large groups of victims, first responders, care providers, and the community as a whole [10]. Managing large groups of people after an incident requires anticipating their likely behaviors during a crisis and designing response plans that are robust in the face of such behavior. Auf der Heide [8] suggests, "Plan for what people are *likely* to do, not what they *should* do."

All large-scale disasters have predictable and recurring patterns [7–9]. In addition to common patterns, hazardous chemical events have unique predictable and recurring patterns that are independent of their cause (accident or deliberate attack) or scale (# casualties, size of region affected).

The inability of the medical system to adequately prepare for these recurring patterns is at least partially due to several commonly accepted misconceptions or myths about what will happen in the presence of a toxic chemical release. These myths are listed in Box 1.

These myths represent what emergency planners *hope* would happen in such events. These myths also represent underlying assumptions that shape how communities prepare for toxic chemical releases. Unfortunately, the reality is much different. As a consequence, emergency planning that is based on these assumptions can be woefully inadequate. To illustrate, four case studies are presented.

Box 1. Common myths about chemical disasters

Myth 1. Hospitals will be notified in advance of arrival of chemically exposed patients.

Myth 2. The offending toxin will be rapidly identified so that on-scene and emergency department care providers will give specific and appropriate treatment.

Myth 3. Dispatchers will send emergency response units to the scene so that trained personnel will triage, treat, and decontaminate victims.

Myth 4. Casualties will be transported by ambulance and they will first transport the most serious patients already decontaminated.

Four case studies

South Carolina train derailment

At 2:40 AM on January 6, 2005, a Norfolk Southern freight train wrecked in Graniteville, South Carolina. The train contained 42 cars including tankers filled with chlorine. The chlorine escaped and created a large toxic cloud that covered a large populated area including a textile mill with 500 night shift workers inside. The consequences of the event: 9 deaths, 529 sought medical care, 18 were treated at area physicians' offices, and 5400 were forced to evacuate in a 1-mile radius of the crash [11]. The Regional Poison Center was initially contacted by a person living near the crash site. She smelled a chemical odor and complained of burning eyes. The poison center promptly called the local ED and found on duty a single emergency physician, who was already overwhelmed with 1 critically ill patient, 6 patients who had pulmonary edema, and 100 patients in the waiting room [2]. The public safety officer at the accident scene notified the ED and suggested that the accident involved a release of sodium nitrate. The poison center researched sodium nitrate's expected health effects from poisoning and found that patients did not exhibit those symptoms. Fifteen minutes later, the chemical was thought to be methanol. Finally, over 1 hour later, the chemical was confirmed to be chlorine. By then the poison center already gave the ED physician human health effects information and treatment recommendations based on the victims' reported clinical presentations.

Tokyo sarin gas attack

On March 20, 1995, at 7:55 AM, terrorists released the nerve agent sarin into the Tokyo subway system [5,12–16]. People became immediately ill and many people rushed from the train cars and subway platforms to the streets. Published accounts of this incident demonstrate a gap between clinicians rendering care and accurate information needed to guide their decisions [5,12,13]. On-scene emergency responders reported to hospitals that an explosion occurred in the subway and they should prepare for victims who have smoke inhalation and carbon monoxide poisoning. The closest hospital, St. Luke's International Hospital, received 500 patients during the first hour of the event. Only 23% of the patients arrived by ambulances while most arrived by walking, taxi, or private vehicle. The first patient arrived by foot and was the hospital's best information source at that time. A delay in identifying the substance and lack of effective communication left hospital staff "blind" until 3 hours after the incident began. Health care providers treated patients without the benefit of knowing the causative agent. They relied on their clinical observations and the scanty and inaccurate information from the scene. Because sarin was not suspected, patients were brought into waiting rooms and other parts of the hospital for treatment without any attention to decontamination. At 11:30 AM, hospitals received word that the victims were exposed to the nerve agent, sarin, a military chemical weapon. They received the information by way of television news broadcast [13]. In the final analysis, approximately 1200 people had signs and symptoms suggestive of at least mild nerve agent poisoning, and 12 died. However, approximately 5500 people sought medical care [4,6]. Also, reports suggest 135 (10%) prehospital providers and 110 (23%) hospital staff developed symptoms of nerve agent poisoning [12,13].

Indianapolis, Indiana industrial accident

In Indianapolis in 1995, the fire department evacuated nearby neighborhoods after realizing that a burning building contained cyanide. Even though air monitoring found no evidence of cyanide, 80 employees at a distant warehouse began to complain of chest tightness, nausea, and dizziness. Patients were transported to the hospital and two patients were treated using the cyanide antidote kit. One patient required ICU admission, not from cyanide toxicity, but from the administered antidote's (sodium nitrite) resulting hypotension and ischemic electrocardiogram changes [4].

Desert storm SCUD attacks

In 1991, during the United States–led Desert Storm operation, 39 Iraqi SCUD missiles landed in Israel [17,18]. These attacks caused over 1000 casualties. One half of the casualties were diagnosed with acute psychologic reactions or acute anxiety. Because it was unknown if chemical weapons were part of the missiles' payload, it appeared that people anticipated toxic chemicals and without verification began to treat themselves. One fourth of the casualties were due to inappropriate autoinjection of atropine because of fear that a chemical nerve agent attack had occurred. Another 40 patients were injured while rushing to a sealed room to avoid chemical exposure. At least 11 deaths were attributed to the missile attacks, although only 2 were from missile trauma. Seven patients (including 1 child) reportedly suffocated from improper use of gas masks, and 4 died of myocardial infarctions.

What really happens in a chemical event?

When a large-scale chemical event happens, the reality is different than the ideal described in Box 1. The authors describe five "*myth-buster*" realities that give a more realistic picture of how a community (people + emergency resources) is likely to respond to a chemical event. These five realities are summarized in Box 2 and further described in this section.

The inevitable consequence of these realities is that the medical response surge capacity can be quickly overwhelmed when faced with a large-scale chemical event [1–6]. This can lead to numerous problems that can significantly erode the effectiveness of the medical response, including (1) failure to treat the most seriously injured patients, (2) mistaken diagnoses, (3) medication errors, and (4) misdirected or squandered medical response resources.

Reality 1: medical personnel are often left in the dark

During the early stages of many chemical events, medical personnel may find themselves operating "in the blind" with little or no understanding about the nature of the crisis they are facing. We refer to this initial period of uncertainty as the *silent gap* because clinicians are left to make critical decisions with little useful input about the nature of the event from

Box 2. What really happens in a chemical event?

Reality 1. Medical personnel must often "operate in the blind" during the early stages of an event.

Reality 2. The offending chemical may not be identified for hours, or even days.

Reality 3. Emergency response personnel seldom have adequate tools or resources to effectively triage, decontaminate, and treat the large numbers of victims of a large-scale chemical exposure.

Reality 4. The first victims arriving at the hospital often arrive under their own power without direct involvement from emergency response personnel on the scene.

Reality 5. The general public can behave in ways that significantly erode the effectiveness of the emergency medical response.

knowledgeable informed sources that are “on the scene” or receive guidance about clinical findings and treatment from clinical experts.

During the silent gap, confirmatory diagnostic test results are unavailable. At this point, clinicians seldom even know what tests to run. Rumors fly as fearful or panic-stricken bystanders and real exposure victims arrive at the hospital with their own (often confused) reports about what has happened or how they feel [10]. During this stage, missing or misleading information about the alleged chemical is common, possibly leading to unnecessary or even inappropriate and harmful therapies. Hospital staff can themselves suffer injury if they fail to use adequate personal protection (as was the case in the Tokyo sarin incident whereby several hospital staff experienced symptoms of nerve agent poisoning through inappropriate handling of victims) [13]. Medical personnel on the scene and at the hospital need clinical guidance from experts. Without such guidance, they are left to improvise, and critical health care resources are misdirected, wasted, or even incapacitated.

Reality 2: the offending chemical may not be identified for hours, or even days

Based on literature published on the case of the Tokyo sarin gas attack, it was over 3 hours before the hospital personnel knew what chemical agent was involved, and this knowledge came from watching the national television news! [13]. After the Graniteville, South Carolina train derailment, the correct identification of the chemical agent came over 1 hour after the event and after several hundred patients had already arrived at the nearest hospital [2].

In the absence of such information, hospital personnel are left to rely upon whatever information they can get from patients (many of whom are merely stunned and bewildered or suffering from acute anxiety), rumor, news reports, and so forth. Such information can be extensive and contradictive.

Reality 3: emergency response personnel seldom have adequate tools or resources to effectively triage, decontaminate, and treat the large numbers of victims of chemical exposure

Many chemical agents commonly produced, transported, or used in the United States are toxic enough to rapidly produce life-threatening conditions. Because the offending agent is often unknown at the beginning, the first responders would need to have ready access to expert guidance to adequately triage, decontaminate, and treat victims at the scene of the event. Unfortunately, responders are often unaware of valuable and readily available information resources, or those resources may not be immediately available because of inadequate development of emergency communication networks [13,19].

It is well understood that the training of medical personnel for response to chemical events should be based on community-specific risk analysis that takes into account the chemicals posing the greatest risk in the community, as well as the potential high-impact scenarios involving those chemicals [20,21]. Unfortunately, most current training and preparation is poorly targeted to community-specific risks [22]. Because this training and preparedness is too generic, specific knowledge, information resources, equipment, and therapeutics may not be available in supplies sufficient to deal with the most likely scenarios.

Reality 4: the first victims arriving at the hospital often arrive under their own power without direct involvement from emergency response personnel on the scene

Following the release of methyl isocyanate in Bhopal, India, an estimated 200,000 people sought medical care [1]. After the sarin attack in the Tokyo subway, 5500 people arrived at nearby health care facilities for medical care [13]. The train derailment releasing chlorine gas in Graniteville, South Carolina caused the evacuation of 5400 people and 529 to seek medical care [2]. In all these cases, many of the first victims to arrive at the hospital come under their own power. Many of these individuals are upset and their fears fuel their sense that they have been somehow affected by an unknown and highly toxic agent. The information they provide to hospital staff can be confusing, contradictory, and misleading.

Reality 5: the general public can behave in ways that significantly erode the effectiveness of the emergency medical response

Abundant examples are found in the literature that demonstrate how a mass chemical exposure will prompt large numbers of people to seek medical care [1–6,23–26]. The greatest numbers of patients seeking care are often those who have or do not have symptoms that perceive they have been poisoned, but do not exhibit obvious signs or symptoms of poisoning. Although many patients experience symptoms based solely on fear or anxiety, some may have an illness that will result in adverse outcomes if not quickly diagnosed and treated. When this occurs during the silent gap (and it almost always does), the ability of the medical system to effectively triage and identify the most critically ill patients is jeopardized. All four of the incidents described earlier illustrate this phenomenon.

Events that subject people to a chemical exposure can be frightening. Many people fear that toxic chemical exposure will inevitably lead to long-lasting ill effects, like an internal chemical time bomb waiting to cause harm years later [12,16,27–30]. In the presence of a reported chemical release, this fear can cause many people to rapidly develop symptoms that do not have an organic etiology. This phenomenon has been called "mass hysteria," "mass sociogenic illness," and "mass psychogenic illness."

Hysteria and other terms deliver a negative connotation to patients. Some prefer ‘‘outbreaks of multiple unexplained symptoms’’ because of these negative connotations [31]. Anxiety is almost always present, but actual hysteria is not a common feature of these events [32]. The physical symptoms reported in these outbreaks are likely manifestations of distress. Affected persons mistake their distress as chemical exposure, which likely contributes to their anxiety and exacerbates symptoms [33].

The trigger is generally a presumption of an exposure to a chemical, and often an unusual odor believed to be associated with a highly toxic chemical induces symptoms [3,26,31,34–36]. Sometimes the inciting event involves exposure to an actual chemical or poisonous substance. At other times, the mere rumor of an exposure can induce symptoms. During an actual release, there will be victims of direct toxicity as well as those that suffer from symptoms that cannot be explained by the exposure [26,37,38]. In fact, some suggest that, after a terrorist incident, the number of individuals who have *not* experienced physical harm but still perceive that they have been exposed may be many times greater than those who are suffering the toxic effects of real exposure [12,13,26,39,40].

Which chemicals should we prepare for?

Common sources of chemical events

To be better prepared, emergency planners must focus on getting the right information into the right hands at the right time. One of the most critical pieces of information is the identity or nature of the offending chemical agent. Access to this information by medical personnel and on-site first responders would dramatically reduce the chaos and its consequences during the early stages of an event. This would give clinicians increased confidence in their therapeutic and disposition decisions.

Given the large numbers of toxic chemicals, this can seem like a daunting task. Before September 11, 2001, training and planning for anticipated deliberate toxic chemical attacks mainly concentrated on chemicals designed specifically as military weapons such as nerve agents, sulfur mustard, and phosgene. Until recently, not much attention was paid to the over 80,000 potentially toxic substances produced, stored, and moved for manufacturing, agriculture, and service industries throughout the United States. Any of these could be released accidentally or deliberately, putting many people in danger.

Because of their availability and toxicity, these chemicals in our communities are increasingly referred to as ‘‘weapons of opportunity’’[41]. Upon release, many of these highly toxic chemicals are readily airborne, leading to inhalation exposure and toxic effects [20].

These chemicals are likely candidates for accidents and for hostile action by terrorists. CBS’s *60 Minutes* aired a segment demonstrating the ease of entering an industrial facility to gain access to large quantities of toxic industrial chemicals [42]. Additionally, a report published by the Government Accounting Office stated that: "…industrial chemicals can cause mass casualties and require little if any expertise or sophisticated methods…can be bought on the commercial market or stolen, thus avoiding the need to manufacture them" [43].

It is unrealistic for first responders or emergency personnel to know these substances in enough detail to make confident decisions during the early phases of a crisis. This approach is not realistic and leads to training that is too generic to be of practical use during an event [22].

On the other hand, it is realistic to train medical personnel for response to chemical events based on community-specific risk analysis that takes into account the chemicals posing the greatest risks in the community, as well as the potential high-impact scenarios involving those chemicals [21,22]. In addition, first responders and medical personnel can learn to rapidly identify potential chemical classes based on toxic syndromes.

Applying basic principles of toxicology for clinical decision-making during mass chemical exposure

The four incidents described earlier make it clear that clinical decision making during an emergency response to a hazardous chemical accident or chemical terrorist attack can be complex and highly uncertain. To do the best for the most, clinicians need a system that rapidly identifies toxicity and guides early medical decisions and antidote therapy. Applying basic principles of toxicology can simplify decision making during mass exposures to toxic chemical events. Identifying toxic syndromes at the bedside and using the dose–response concept to assess toxic chemical exposure can be helpful.

Toxicology principle 1: using toxic syndrome recognition for rapid diagnosis and empiric therapy

Tens of thousands of chemicals are harmful to humans, and knowing the specific toxic effects of even a large portion of the possible chemical agents would be an impossible task. Toxic chemicals can often be grouped into classes, whereby all the chemicals in a given class cause similar human health effects. These constellations of toxic effects or *toxic syndromes* comprise a set of clinical "fingerprints" for groups of toxins [44–47]. Moreover, all the toxins associated with a given toxic syndrome are treated similarly. Hence, during the early phases of a toxic chemical emergency, when the exact chemical is often unknown, identification of the toxic syndromes that are present can be a useful decision-making tool that can overcome many of the problems associated with the silent gap. For example, narcotic overdoses that arise from substance abuse, accidental overmedication, or accidental ingestion of prescription medications cause a predictable constellation of clinical findings (pinpoint pupils, coma, and respiratory depression) that are well known and readily identified by all health care providers in the emergency medical system (first responders, paramedics, medical and nursing students, nurses, and physicians) [48]. The identification of this constellation of signs and symptoms is all that is needed to diagnose narcotic overdose. This immediately alerts the health care provider to a treatable life-threatening condition (eg, respiratory arrest). Once identified, any health care provider at the scene or in the hospital will take action by administering naloxone, the specific antidote for all narcotic overdoses. At this stage of treatment, it does not matter if the offending agent is morphine, heroin, oxycodone, or any other narcotic. The clinical condition is the same, the initial treatment is the same, and the anticipated complications are similar. Once the life-threatening crisis has been averted and time passes, more specific information from the history or diagnostic test results will guide additional therapeutic decisions and patient disposition.

Toxic syndromes are easily identified with only a few observations, such as:

- Vital signs
- Mental status
- Pupil size
- Mucous membrane irritation
- Lung exam for wheezes or rales
- Skin for burns, moisture, and color

Toxic syndrome recognition is important because it provides a tool for rapid detection of the suspected cause and can focus the differential diagnosis to consideration of only a few chemicals with similar toxic effects. Table 1 [49,50] lists readily recognized toxic syndromes that are likely to be observed in mass chemical exposures. By focusing on certain chemicals, specific diagnostic testing and empiric therapies can be rendered based on objective clinical evidence. Specifically during a mass exposure, recognition can provide a triage tool for identifying exhibiting toxic effects and also provide a common ‘‘language’’ so that emergency responders from the scene through to the hospital ED can clearly communicate a clinical message.

With the extraordinary number of chemicals in use, this tool does not apply to every chemical but to most of the commonly encountered chemicals reported in HazMat incidents. Other toxic effects caused by chemicals include hematologic injury such as methemoglobinemia or hemolysis, liver and kidney injury, and peripheral neuropathies. These less-common toxic effects may require the assistance of a medical toxicologist to guide work-up and medical management.

The use of toxic syndromes as a diagnostic tool is fundamental to an effective medical response. However, the degree to which the toxic symptoms present themselves depends on both the route of exposure and the dose.

Table 1
Common toxic syndromes observed in mass chemical exposures

Toxic syndrome	Common signs and symptoms	Examples
Irritant gas syndrome	Eye, nose, and throat irritation, cough, wheezes, shortness of breath, chest pain Caution: may have a delayed presentation	Ammonia, chlorine delayed presentation seen with phosgene and nitrogen dioxide
Chemical burns	Painful burning skin, mucous membrane irritation, systemic effects	Hydrochloric acid, hydrofluoric acid, hydrocarbon solvents such as degreasors and defatters
Organophosphate Insecticide poisoning (Cholinergic storm)	Pinpoint pupils, eye pain, shortness of breath, wheezes, rales, sweating skin, drooling, tearing, vomiting, diarrhea, fasciculations, coma, seizures	Organophosphate and carbamate insecticides, nerve agents
Acute solvent exposure	Headache, lightheadedness, nausea, mucous membrane irritation, confusion, syncope	Paint thinners, degreasors and lubricants, toluene, methylene chloride, trichloroethylene,
“Knock-down” or metabolic poisoning	Rapid loss of consciousness, seizures, hypotension, cardiac arrest	Cyanide, hydrogen sulfide, phosphine
Behavioral response to the fear of chemical exposure “The fear factor”	Lightheadedness, shortness of breath, chest pain, faint, nausea, sweating skin, palpitations, tremor	Often “fight or flight” stress response from fear. CAUTION: low level exposure to toxins can resemble this response

The toxic syndromes listed in this table are derived from expected clinical effects after exposure to those chemicals most often reported to be involved in accidental spills, those with likelihood of causing significant health impact upon release, and those with emergent treatments available (eg, cyanide and nerve agent poisoning) [20,49,50,58].

Toxicology principle 2: route of exposure is a determinant of toxicity

A chemical’s physical state and the route of exposure influence toxicity [51]. The chemical’s state often determines the route of exposure. Gases, vapors, airborne powders, and aerosolized liquids are inhalation risks. For many chemicals, the toxic effects occur at the site of absorption. For example, irritant gases attack the water in the respiratory mucosa and eye, causing burning pain, irritation, and copious secretions at the site of contact. Inhalation exposure also allows some rapid entry into the systemic circulation, causing toxic effects distant from the entry route. Hydrogen cyanide is a gas that rapidly enters the circulation through the lung and causes loss of consciousness, seizures, cardiac dysrhythmias, hypotension, and possible death in a matter of minutes after the exposure.

Chemicals in contact with the skin can cause local effect but may also enter the systemic circulation and cause effects at distant sites from the entry route. Organophosphate insecticides are fat-soluble chemicals that rapidly penetrate the skin and enter the blood stream to circulate to distant sites. Skin exposure can delay onset of systemic effects as compared with the rapid entry through the lung.

Toxicology principle 3: the dose makes the poison

Paracelsus, a 15th century scientist, made this claim: ‘‘What is it that is not poison? All things are poison and nothing is without poison. The right dose differentiates a poison from a remedy’’ [51]. Evaluating clinical effects based on the amount of exposure is a basic toxicology principle called dose–response [51]. The dose is the total amount of chemical absorbed during an exposure. It depends on the concentration of the chemical *and* duration (contact time) of the exposure. Chemicals cause predictable toxic effects based on the dose. Ethanol is a good example. Incremental increases in blood ethanol levels result in predictable increases in alteration of consciousness (signs of inebriation), poor coordination, and eventually coma/respiratory depression, and finally death [52].

One important factor affecting the dose is the duration of the exposure. High concentrations over a long duration are more likely to produce adverse health effects than the same or lower concentration over a shorter exposure period. An acid placed on the skin will cause more tissue destruction the longer it stays in contact with the tissues. If the acid is immediately washed off the skin, injury is limited [53]. The same is true for inhaled chemicals. The longer a victim is allowed to breathe toxic chemicals, the greater the dose of exposure.

Applying these dose–response principles can guide patient assessment to toxic chemical exposures. Patients who have higher concentrations and longer durations of exposure result in greater doses to the victim and will more likely have harmful effects. Those receiving larger doses need more urgent attention and possibly life-saving interventions than those receiving smaller doses (especially if asymptomatic).

The dose determines the poison during triage. Determining if a patient had direct contact (eg, splash or skin contact) and the relative distance from areas with the highest concentrations (eg, near the source of a leak or spill) can guide triage decisions, just like principles of radiation dose delivery (ie, time, shielding, distance) apply to many mass chemical events [54]. Obtaining history about the time a patient was in a toxic environment and the distance from the areas of greatest concentration can help to stratify patients into high-risk and low-risk groups. This approach is similar to using an account of the mechanism of injury to anticipate injuries even before the clinician touches the trauma patient. Understanding the different mechanisms of trauma (eg, speed of the vehicle, presence of fatalities in the same accident, or height of a fall) and the predictable pattern of injuries that may result will influence the patient's evaluation and affect care. This approach is not an absolute solution for poisonings but is potentially valuable for mass chemical exposures whereby triaging patients is critical to quickly find those most at risk for serious illness.

In addition to triage, the same principles can guide treatment strategies for hazardous chemical exposures. The most basic treatment objective is to limit exposure time and decrease concentration as rapidly as possible. Moving rapidly away from a vapor cloud in an accidental release is common sense and illustrates the point of decreasing concentration and duration of exposure. Similarly, deluging with water after splashing a concentrated sulfuric acid on the skin will decrease the chemical's concentration and the duration of exposure [53].

Doing the best for the most: a strategy for putting it all together

A community could devise an effective response strategy if it focused on: (1) planning for expected challenges to the emergency response and health care systems, (2) identifying the greatest chemical risks that could cause harm if accidentally or deliberately released, and (3) using critical decision pathways during the emergency response that apply basic toxicologic principles. Such a strategy should place a high priority on:

- Rapidly recognizing situations and clinical presentations suggesting a hazardous chemical accident or chemical terrorism attack is in play
- Taking actions to close the silent gap
    - Creating a community-specific risk assessment to determine the most likely chemicals to be involved in an accident
    - Use a tiered response strategy
    - Creating a communications network to effectively manage information
- Providing medical care that will do the best for the most victims of the incident

Rapidly recognizing situations and clinical presentations suggesting a hazardous chemical accident or chemical terrorism attack is in play

Much emphasis is placed on proper personal protective equipment and specific steps in the decontamination procedure [21,55,56]. Although these principles are important, *the single most important step toward protection and excellent patient care is to recognize suspicious situations and clinical presentations that are likely to be related to chemical exposure. This recognition will lead to ACTION!* Plans cannot be activated nor any actions taken unless a high-risk situation is recognized. After the sarin attack in the Tokyo subway, the first patient to arrive walked into the ED soon followed by over 500 additional patients [5]. For the first few hours, the staff did not recognize that the situation could be from a toxic chemical exposure and did not recognize the specific toxic syndrome caused by nerve agents [13]. Because they were unaware, patients were escorted into the hospital fully clothed.

Chemical contamination and toxic effects may often go unrecognized because health care providers are distracted during early stages of an incident by multiple victims who have traumatic injuries, sudden unconsciousness, or unexplained cardiac arrest, and by the large number of patients seeking care. Therefore, prehospital and ED personnel must be alert for high-risk situations. Triage personnel, in particular, should be trained to recognize high-risk situations that could send chemically contaminated patients to the ED. Nearly all ED evacuations/closures have been related to lack of early recognition and high levels of concern about the potential for secondary contamination, and not the lack of a written protocol or dedicated decontamination equipment [57].

Examples of situations that should raise the suspicion of a chemical exposure:

- Victims exhibiting signs and symptoms of specific toxic syndromes
- Industrial accidents, fires, or explosions
- Transportation accidents
- Agricultural accidents
- Clandestine drug laboratory accidents
- Sudden onset of illness in large groups of people from crowed areas (especially government, political, or religious places)
- Victims noticing chemical odor or vapor cloud

Recognizing a toxic syndrome serves as a detection tool or early alert system for recognizing a potential hazardous chemical exposure. Recognizing these syndromes should lead staff to take protective actions. Physicians assisting victims in the Tokyo sarin subway attack stated: "We suspected the cause of the victims' illness was some form of organophosphate agent exposure. We were puzzled as to why it had happened in the subway" [13]. They recognized the syndrome and empiric treatment followed.

Taking actions to close the silent gap: create a community-specific risk assessment to determine the most likely chemicals to be involved in an accident

Lessons from the past demonstrate the silent gap exists in most incidents involving hazardous chemicals. Specific preparedness activities and a structured response strategy can decrease this period of uncertainty about causative agents and give the clinician objective data to assist in critical clinical decisions, thus closing the silent gap.

Because a virtually limitless list of potentially devastating "weapons of opportunity" are available for use in a terrorist attack or are at risk of being accidentally released, an overwhelming body of knowledge is required for health care providers to master and use in this chaotic decision-making environment. Moreover, because events involving such agents are not an everyday occurrence in any given community, the benefits of training can rapidly decay through lack of use. Instead, a realistic strategy should focus on chemicals used, manufactured, or stored in the local community. Specific industrial activities are more prone to errors and chemical accidents. Burgess found that agricultural manufacturing; petroleum refining; industrial chemical manufacturing; electric, light, and power production; and paper mills had the highest number of hazardous chemical events [58]. Data like these should alert community planners to the industries (and their commonly used or manufactured chemicals) as the most sources of chemical accidents. Transportation accidents add a level of complexity to planning because of the vast array of chemicals that flow through a community by highway, rail, or waterway. Compared with other transportation accidents, railroad accidents are specifically prone to impact public health, and certain chemicals are readily identifiable that are carried in mass quantities by railand have a significant risk to public health if released in an accident [59].

Throughout history, inhalation of toxic gases has subjected the greatest number of people to harm [1,60,61]. Chemicals with specific characteristics are more likely to affect large numbers of people if released in an accident or used as chemical weapons of opportunity [20]. First, the chemical must have inherent toxicity. Next, it must readily become airborne allowing movement away from the point of origin. Finally, it must be available in quantities large enough to deliver dangerous concentrations to nearby large populations. Therefore, the highest priority planning must focus on those chemicals in each community with these characteristics. Knowing the high-risk chemicals in a community can direct emergency response planning and training efforts by providing advance knowledge of their unique characteristics, clinical effects, and therapies. Knowledge and preparation can shorten the silent gap.

Taking actions to close the silent gap: use a tiered response strategy

A crucial therapeutic goal of an emergency response to mass chemical exposure is the timely administration of appropriate life-saving treatments to patients most needing them. This goal is realistic if a response strategy is built around rapid detection of toxic syndromes. During mass exposures, it is not easy to distinguish patients most urgently needing care from the large number of patients that are likely to actually seek care. Delaying treatment of patients needing immediate care will result in increased morbidity and mortality.

Identifying toxic syndromes is an approach that will help bridge the silent gap by helping providers focus on the most critical empiric observations. This strategy eliminates the need for mastery of detailed information about a multitude of chemicals while still guiding rapid and appropriate actions that may make a difference in patients' outcomes.

Using toxic syndrome recognition as the foundation, a tiered community response strategy can be built. The elements in the strategy are:

1) Initial patient assessment: using toxic syndromes as a diagnostic framework, medical personnel identify the toxic syndrome(s) present in the victims.
2) Staff protection: based on the toxic syndrome(s) identified, medical personnel (prehospital care providers and hospital staff) refer to "just in time" training to guide efforts at personal protection and decontamination of staff and victims.
3) Empiric treatment and antidote administration: the knowledge of the toxic syndrome immediately identifies the most appropriate treatment options including time urgent and life-saving antidotes (eg, Mark 1 kits and cyanide antidotes).
4) Confirmation of causative chemicals: the toxic syndrome narrows down the list of potential causative chemical agents to a manageable level. This in turn provides guidance to clinicians about which tests to run to identify and confirm the specific agents involved, thereby assuring that laboratory resources are applied in the most effective way possible. In addition, over time, several lines of investigation, such as scene analyses or factual details of the incident, will help to clarify/confirm the identity of the causative chemical.
5) Chemical-specific therapies: once the specific causative agents are identified, medical personnel are able to administer any chemical-specific therapies that might be needed and make more informed decisions about patient disposition.

This tiered strategy presupposes that hospital staff has on hand the appropriate antidotes, protective equipment, and so forth to adequately respond to any given chemical event. Unfortunately, this is often not the case [22,62]. Gursky [63], Rubin [64], and Treat and colleagues [65] indicate that most hospitals are woefully unprepared for and unaware of chemicals that pose the greatest threats and potential for casualties in their communities (either by attack or accident). Moreover, during the early stages of a chemical event (ie, during the silent gap), the effectiveness of the medical response depends on the diagnostic capabilities of personnel "on the scene" who often have limited medical training. The community-specific risk assessment can direct advance planning for the medical response community so they possess specific knowledge, equipment, and antidotes for the most likely events. Moreover, applying toxic syndrome recognition to a tiered response will give clinicians a higher degree of certainty about causative agents and objective data to assist in critical clinical decisions. Applying the tiered response to this level of preparedness and certainty will close the silent gap, thus optimizing the emergency response capabilities.

Taking actions to close the silent gap: create a communications network to effectively manage information

The case examples previously described demonstrate the susceptibility of communications to fail and is often reported in ‘‘lessons learned’’ analyses [7–9]. In hazardous chemical accidents, accurate and reliable information is a resource, and information management is a key component of an effective response. Responders and health care providers at all levels must be able to readily exchange information. This requires a common ‘‘language’’ with which to describe events as they unfold. The use of toxic syndrome identification provides that common language and set of diagnostic criteria for staff located at the hospital and for emergency personnel who are at the scene of the event.

Information gathered by on-scene personnel must be relayed to hospitals before the wave of patients converges on the ED. To provide the best care possible, clinicians must rapidly access reliable information regarding human health effects and treatment. In response to the Tokyo subway sarin attack in 1994, physicians suggested ways to correct the observed problems during their emergency response [13–15]. They observed that the most significant problems with communications were a lack of an efficient chemical disaster information network and that poison information centers should act as regional mediators of all toxicologic information. They suggested that police, fire departments, self-defense forces, poison information centers, and hospitals need to form an information network. The regional poison centers’ abilities to acquire and disseminate information in a crisis makes it a critical information resource in the communications network [13,19].

Providing medical care that will do the best for the most victims of the incident

‘‘Doing the best for the most’’ is challenging when confronted with a mass chemical exposure. For the most part, medical management requires the sequential recognition of four different classes of medical needs.

I: Patients needing decontamination

It is essential to recognize patients who have harmful chemicals still in contact with their skin and clothing. The purpose of decontamination is to prevent further harm to the patient and to swiftly deliver a ‘‘clean’’ patient to the treatment area. A toxic chemical’s contact time and concentration are determinants of the extent of injury [51,53]. Therefore, decontamination is a FIRST AID procedure. Rapidly remove contaminated clothing, and copiously irrigate contaminated skin or eyes with water. The second reason to decontaminate a patient is to prevent the spread of contamination away from the scene and avoid secondary contamination to health care providers. Every patient at a hazardous chemical incident does *not* need a full decontamination [66]. Deciding to decontaminate every victim at the scene will overwhelm the response system and impede medical care. A detailed discussion about patient decontamination is beyond the scope of this article but is reviewed in detail elsewhere [21,55,56,66].

II: Patients needing immediate life-saving care (advanced life-support measures)

After decontamination, treatment of victims exposed to toxic chemicals primarily involves symptomatic and supportive care. Most critically ill poisoned patients have acute reversible conditions requiring supportive care measures. Many times, supportive care measures alone will improve the outcome of critically ill poisoned patients by focusing on maintaining a patent airway, preventing hypoxia, and treatment of shock. Valuable resources, such as antidotes, may be in limited supply during a mass chemical exposure. Decisions about aggressive resuscitation efforts and use of resources must take into account a patient's likelihood of survival.

III: Patients needing urgent antidote therapy or other specialized therapy

Few specific antidotes exist for hazardous chemical exposures; therefore, recognizing syndromes caused by chemicals treated with specific antidotes avoids blindly administering antidotes to patients who do not have clear indications. Clinicians must immediately recognize the toxic syndromes caused by nerve agents and cyanide and rapidly administer specific antidotes to give critically ill patients the best chance of survival.

IV: The psychologic needs of patients, families, care providers, media, and the community

The greatest diagnostic challenge for evaluating a patient who has potential poisoning is determining if the patient's problem is due to direct toxic effects of chemicals. Patients who have obvious contamination or signs of poisoning need immediate medical attention. Several patients will be asymptomatic but fearful of being poisoned and will seek medical care for reassurance. The greatest number of patients seeking care is often asymptomatic and symptomatic who are perceiving poisoning but not experiencing obvious signs or symptoms of poisoning [5,13]. Low-level exposure to highly toxic substances can cause nonspecific symptoms similar to those reported for perceived poisoning. For example, patients who have mild to moderate nerve agent poisoning after the 1995 Tokyo sarin attack reported nonspecific signs and symptoms such as chest tightness, dyspnea, tachycardia, nausea/vomiting, abdominal cramps, headache, and diaphoresis [5]. During a mass chemical exposure, the diagnosis of fear and anxiety is by exclusion only.

Nonspecific symptoms caused by the autonomic arousal from fear and anxiety seem to be contagious and has been called "crowd poison" [67]. Strategies to prevent spread include separating patients into small groups and removing patients from “line of sight” activities such as the presence of ambulances, fire trucks, television cameras, and workers in protective clothing. These sights and sounds signal that the situation is dangerous and enhance anxiety [34].

Delivering information and reassurance during a crisis requires risk communication skills [68–70]. The goal of risk communication is to provide people with accurate information and alleviate anxiety that stems from rumor and misinformation. Information is an antidote to fear, because those who have more knowledge regarding the risks of exposure improve their attitudes toward those exposures [31]. Important principles of risk communication include recognizing and responding to the emotional response (outrage) to risk mostly by listening to patients’ concerns. People need a sense of control, and providing specific actions will give patients some sense of control [68].

Summary

An accident releasing hazardous chemicals or a deliberate chemical terrorism attack will create chaos, confusion, and seeming unpredictability that complicates the emergency response. Clinicians are challenged to urgently treat victims needing care, even before a chemical is confirmed. One of the first steps toward preparedness is to gain some sense of control by anticipating the “most likely” challenges learned from past events. Predictably, the medical response can be overwhelmed when faced with a large-scale chemical event leading to numerous problems that can significantly erode its effectiveness. An effective response strategy should: (1) plan for these predictable challenges to the emergency response and health care systems, (2) identify the greatest chemical risks that could cause harm if accidentally or deliberately released, and (3) use critical decision pathways during the emergency response that apply basic toxicologic principles. Emergency planning that focuses on these areas can bring a sense of order to the chaos and provide medical care that will do the best for the most victims of the incident.

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