EMERGENCY DEPARTMENT RESPONSE TO HAZARDOUS MATERIALS INCIDENTS

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Emergency physicians respond to many critical situations with confidence. A toxic chemical accident bringing one or hundreds of victims to the emergency department (ED) will be a unique situation for most emergency physicians. Preparation is important not only for a victim's outcome but also for the safety of hospital personnel. Most emergency care providers (prehospital or hospital-based) rush to aid victims without thinking of the potential danger to themselves. Treating victims of toxic chemical accidents requires stepping back and assessing the situation before acting; otherwise, the would-be rescuer may become a victim. Fire Services and Emergency Medical Services (EMS) have surpassed hospital personnel in educating and training themselves to respond appropriately to toxic chemical accidents. Unfortunately, this makes the hospital response to a toxic chemical accident one of the weakest links in a community's response. Are the emergency physician and the ED really prepared to confidently handle patients exposed to toxic chemicals?

Unfortunately, many hospital mass casualty incident (MCI) plans are complex, untested documents intended to meet certification requirements. Often these plans do not even consider the response to a hazardous materials (Haz-Mat) incident. Most commonly, MCI plans are written to respond to incidents where traumatic injuries are common, such as plane crashes. Many hospital MCI plans will not be adaptable to Haz-Mat incidents because evaluation and treatment of chemically contaminated patients is not routine. In Haz-Mat incidents, the causative agent(s) may not be identified, and the pathophysiology is less familiar. Treatments, such as administering extremely large doses of atropine for organophosphate poisoning, may be unfamiliar and unconventional. Additional

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casualties may occur because rescue workers become ill or many people develop symptoms from mass psychogenic illness.[36]

RECOGNIZING HAZARDOUS MATERIALS INCIDENTS

Hazardous materials are substances that may injure life and damage the environment if improperly handled. Hazardous materials are not dangerous if properly contained but can be extremely dangerous following uncontrolled release from their containers.[17, 63] For example, chlorine is not harmful until the truck carrying it overturns and it escapes into the environment. In 1986, 587 chemical releases that resulted in deaths, injuries, or evacuations were reported in the United States.[7] In that year, 115 deaths and 2254 injuries were attributed to toxic chemical releases. These accidental releases frequently occur at industrial sites, chemical manufacturing plants, pipelines, waste sites, and transportation (truck and train) accidents.[82] Table 1 lists frequently reported chemicals associated with releases resulting in significant sequelae.

Effective management of a Haz-Mat incident requires rapid recognition that a hazardous chemical is involved. Recognition of chemically contaminated patients may be difficult because they often present to the ED for other reasons. Contaminated patients may arrive with multiple traumatic injuries from a fall or motor vehicular accident, sudden unconsciousness, or unexplained cardiac arrest. Table 2 lists situations in which hazardous chemical contamination is highly possible.

A Haz-Mat incident may involve only one victim, such as a person overdosing on a pesticide, or numerous casulaties.[33] The emesis, secretions, and chemical-soaked clothing of one victim can be hazardous materials. In an unprepared ED, one contaminated patient may disrupt operations of the entire department, overwhelm staff, deplete supplies, and create a disaster. Likewise, a mass casualty incident involving a hazardous chemical release, such as the release of methyl isocyanate in Bhopal, India, can overwhelm the hospital with multiple victims and is the most extreme Haz-Mat situation a community can face.[58, 63]

The actual risk to the staff caring for a chemically contaminated patient in the ED is difficult to estimate. Unlike survey meters for identifying radiation contamination, no procedure is available to rapidly detect chemical contamination on patients. Reports of ED evacuations and ED personnel becoming ill due to chemical contamination illustrate that the risks are real.[1, 33, 62, 91] In the ED, inhaled toxins can overcome staff and skin contact can cause burns or systemic effects. Once the potential risk of chemical contamination has been recognized, a plan must be implemented that provides rapid emergency care to patients and protects staff, patients, and the facility.

Table 1. MOST COMMON CHEMICALS REPORTED IN ACCIDENTAL RELEASES THAT HAVE RESULTED IN DEATHS, INJURIES, OR EVACUATIONS

Pesticides	Corrosives
Organophosphate insecticides	Sodium hydroxide
Gases	Sulfuric acid
Natural gas (liquefied petroleum gas)	Hydrochloric acid
Chlorine	Fuels
Ammonia	Diesel oil
	Gasoline

Data from references 7 and 91.

Table 2. CIRCUMSTANCES THAT SUGGEST CHEMICAL CONTAMINATION

Industrial accidents (especially chemical manufacturing plants)
Explosions, fires, pipeline ruptures, spills, falls
Agricultural accidents
Transportation accidents
Trains, trucks, planes (cropdusters), ships
At the scene
Vapor clouds
Dead animals or fish
Multiple patients with same complaints
Rescue from an enclosed space
If a patient has
Unconsciousness ("found down")
Unexplained cardiac arrest
Strong odors on skin or clothing
Unidentified liquids or powders on skin or clothing
Chemical burns
Overdoses involving cleaning or agricultural chemicals
Methemoglobinemia
Irritation of skin, eyes, mucous membranes and respiratory tract
Neurologic complaints (numbness, weakness, seizures)

EMERGENCY RESPONSE TO A HAZ-MAT INCIDENT

Information Management

Information management is crucial to effective disaster management (Table 3).[23, 90] A lack of centralized information sources or even total lack of communications are recurrent problems in all types of disasters.[23, 29, 40, 44, 90] Timely and accurate information provides the best opportunity for an organized response to a Haz-Mat incident. Effective communication with involved agencies is essential during all stages of a response.

Hospital notification of an incident must occur as soon as possible from the scene to allow preparation for receiving contaminated patients. Thoughtful decisions and advanced preparation can mean the difference between effectively handling a situation and turning the hospital into a disaster zone. Decisions made in the early stages of a disaster are very important because mistakes tend to be magnified many fold as the response progresses.[90] Information should come from as close to the source as possible, for example, the incident commander at the scene.

Identifying Toxic Chemicals and Assessing Hazardous Environments

Toxin identification must begin before patients arrive in the ED (Table 4). Rapid identification provides maximum time to determine potential toxic effects and appropriate therapy.

EMS and Haz-Mat response teams are trained to identify unknown chemicals released into the environment. Placards, shipping papers, United Nations (UN) chemical identification numbers, markings on shipping containers, and on-scene chemical analysis are used to identity offending agents. Information from the scene including the above data, nature of the accident, odors, and observed

Table 3. CHECKLIST FOR RESPONDING TO A HAZ-MAT INCIDENT

- Verify nature and extent of incident
  - Type of incident (gas leak, fire, transportation accident)
  - Type of facility (manufacturing plant, storage facility, research facility)
  - Number of victims and severity (Any deaths?)
  - Suspected toxin(s) (radiation?)
  - Symptoms observed
  - Treatment rendered and type of decontamination
  - Associated problems (cardiac arrest, trauma, burns, etc.)
- Further toxin identification (*see* Table 4)
  - Consult with scene personnel (public safety, plant officials)
  - Identifying documents (MSDS, placards, bill of lading)
  - Additional clues (odors, toxidromes)
- Assess health risks (*see* Table 5)
  - Consult Regional Poison Center/Medical Toxicologist
  - Consult references (computer databases, textbooks)
- Provide initial medical advice to the scene
  - Triage decisions
  - Decontamination procedures
  - Specific treatment
- Prepare for patient arrival
  - Activate mass casualty incident plan (if necessary)
  - Disposition of patients in ED
    - Admit or discharge
  - Assign specific duties to ED personnel
  - Establish patient care areas (*see* Fig 1)
    - Secure ED entrances
    - Define patient flow in and out of ED
    - Establish "Hot Zone"
      - Triage
      - Decontamination
      - Resuscitation
    - Decontamination containment area ("warm zone")
    - Support area ("cold zone")
- Put on personal protective equipment (PPE)
- Receive patients
  - Personnel protection is top priority
  - Initially evaluate patients outside of ED
  - Triage
  - Decontamination (*see* Table 6)
  - Resuscitation
  - Move to treatment area (warm or cold zone)
- Definitive care
  - Primary survey (Airway, Breathing, Circulation)
  - Secondary survey
    - Look for toxidromes
    - Treat specific problems
      - CNS: coma, seizures
      - Cardiovascular: dysrrhythmias, hypotension
      - Pulmonary: bronchospasm, pulmonary edema
    - Use specific antidotes and treatments (*see* Table 7)
- Inform public/media about incident
  - Provide accurate and timely information
  - Recommend specific actions: first aid, nearest shelter
- Wrap-up
  - Arrange follow-up for patients
  - Address clean-up and environmental concerns
  - Address risks for long term health effects from exposure
    - Staff
    - Patients
  - Debrief staff
  - Critique ED response and revise plan

Table 4. STEPS TO IDENTIFYING CHEMICALS AND OBTAINING HEALTH RISK INFORMATION

- Suspect the presence of hazardous materials (*see* Table 2)
- Attempt to identify toxin
  - Consult with scene personnel for data
    - Use information from placards, labels and available documents
      - Categorize by hazard class (National Fire Protection Agency): such as oxidizers, corrosives, radioactive
      - Determine specific chemical name
        - United Nations (UN) or DOT numbers: for example #1051 is hydrogen cyanide and #1052 is anhydrous hydrogen fluoride
        - Use available documents
          - Shipping papers
          - Material Safety Data Sheet (MSDS)
    - On-scene chemical detection
      - Direct measurement devices
      - Colorimetric analysis
      - Portable photoionization devices
  - Contact Regional Poison Center with information or put Poison Center in contact with incident commander
  - Use available information resources (*see* Table 4)
    - Agencies
    - Computer databases
    - Textbooks
- Determine risk of toxicity
  - Discuss with Poison Center/Medical Toxicologist
  - Use available resources (*see* Table 4)
    - Computer databases*
    - Textbooks*

*Do not rely on a single reference source for information. Attempt to verify information from two other reference sources

symptoms can help identify toxic chemicals. Reported signs and symptoms may suggest a toxic syndrome such as the cholinergic syndrome from organophosphate poisoning.

Specific chemicals may be detected at the scene of an incident. Emergency physicians must be aware of the common techniques of on-scene chemical analysis that are used to evaluate dangerous environments.[83] Instruments are available that directly measure carbon monoxide, cyanide, hydrogen sulfide, oxygen, and combustible gases. Colorimetric detector tubes can determine the presence and approximate concentrations of chemicals in environmental air samples. Alpha, beta, and gamma radiation detectors detect radioactive contamination. Portable photoionization, infrared, and flame ionization devices are available for more sophisticated measurements that may precisely identify a chemical or determine a broad chemical category such as oxidizing agent or corrosive. Physicians may be requested to give the clinical significance of the level of a toxin reported from the field. *The detection of a specific chemical at the scene does not imply a patient has had a toxic exposure to the chemical nor does it confirm the etiology of a patient's illness.*

Once the chemical is identified, health risks should be assessed. Most sources of hazard information assess risks to the environment and may not be reliable concerning human toxic effects and treatment. Material Safety Data Sheets (MSDS) are good resources for chemical identification, but the information on

human health effects and treatment is often incomplete or inaccurate.[9, 38, 44, 56] Ingredients listed on the MSDS as inert may actually be toxic substances. Acute toxicity levels, such as immediately dangerous to life and health (IDLH) and short-term exposure limit (STEL), apply to occupational exposures and are not useful for acute environmental exposures.[4, 95] The Regional Poison Center can be extremely helpful in identifying chemical names from placards and chemical code numbers. In addition, Poison Centers and Medical Toxicologists are the best resources for up-to-date human health risk information and specific treatment recommendations.[57] Table 5 lists important resources to help with medical information.

Review Hospital MCI Plan

Once notified of a Haz-Mat incident, the emergency physician should implement the hospital's MCI plan if necessary. The portions of the plan regarding chain of command and establishing a hospital command center and a list of key contacts should be reviewed.

Defining who is in charge is essential for effective communication. Leaders (e.g., physician-in-charge, triage physician, and charge nurse) should be easily identifiable by wearing a recognizable symbol such as a brightly colored vest. The emergency physician is likely to be in charge early in the response, but administrative duties need to be delegated once additional help arrives.

Establish a hospital command center to serve as a centralized supervisory and communications resource. Ideally the command center is staffed by a physician, nurse, and administrator, and contains multiple telephones and two-way radios.[3] The command center should quickly establish objectives and a plan to accomplish each task. Because communications are so critical, the command center's focus should be information management. The command center collects and evaluates information from the scene, ED, patient care areas, local hospitals, and the Regional Poison Center. It can coordinate patient distribution with other hospitals and arrange interhospital transfers after initial patient resuscitation, if a unique service is only available at another institution (e.g., hyperbaric oxygen, pediatric intensive care unit). It can also provide information to the media and to families of victims.

Communicating Risks to the Press and Public

Informing the media and public about an incident may not appear a priority when patients need the medical staff's undivided attention. However, it is extremely important to enlist a credible spokesperson for the hospital. The public often mistrusts governmental agency representatives but perceives emergency physicians as trusted spokespersons for the community.[53, 59] The public's perception may be based on emotional responses that overestimates risks if insufficient information is given.[5, 73, 81] The psychosocial response to a Haz-Mat incident may lead to mass psychogenic illness with signs and symptoms resembling a true toxic emergency.[8, 25, 36, 80] Accurate and timely information will prevent rumors and can alleviate many fears associated with a toxic exposure.[80]

A Haz-Mat disaster does not end when the last acutely ill patient is decontaminated and treated. Contamination of air, soil, food, pets, livestock, and drinking water may produce delayed toxic effects throughout a community. In addition, posttraumatic stress syndrome is prevalent following all types of

Table 5. IMPORTANT RESOURCES FOR EMERGENCY HAZ-MAT RESPONSE AND PLANNING

Agencies

- **Regional Poison Center**
  24-hour toxicology information
- **Health Department**
  Assist with public health and follow-up care
- **Local Emergency Planning Committee (LEPC)**
  Provide information about chemicals in community
- **Fire Department/Hazardous Materials Team**
  Assist with response and planning
- **Chemical Transportation Emergency Center (CHEMTREC)**
  24-hour information resource to manufacturers product information (phone number: 1-800-424-9300)
- **Agency for Toxic Substances and Disease Registry**
  24-hour emergency assistance for health-related issues (phone number: 404-639-0615)
- **Environmental Protection Agency**
  Regional offices with technical assistance available for environmental issues
- **National Response Center**
  Provides 24-hour assistance for identifying chemicals and planning a response (phone number: 1-800-424-8802)
- **Radiation Emergency Assistance Center/Training Site (REAC/TS)**
  Provides emergency consultation for accidents involving radioactive materials (phone number: 615-481-1000)

Computer Databases

- **Chemical Hazard Response Information System (CHRIS)**
  Contains general and health hazard information (for more information: 1-800-247-8737)
- **Hazardous Substance Data Bank (HSDB)**
  Reviews toxicity information compiled by the National Library of Medicine (for more information: 301-496-6531)
- **Poisindex/Tomes**
  Contains comprehensive acute and chronic toxicity information (for more information: 1-800-525-9083)
- **Toxicology Data Network (TOXNET)**
  National Library of Medicine data bank for health effects of industrial and environmental exposures (for more information: 301-496-6531)

Publications

- Sullivan, Krieger. Hazardous Materials Toxicology: Clinical Principles of Environmental Health, Williams & Wilkins, 1992
- Borack, Callan, Abbott: Hazardous Materials Exposure: Emergency Response and Patient Care, Prentice Hall, 1991
- Agency for Toxic Substance and Disease Registry: Managing Hazardous Materials Incidents: Volume II: Hospital Emergency Departments, 1991
- 1987 Emergency Response Guidebook, ed 4. US Department of Transportation (DOT), 1987

General Toxicology Texts

- Ellenhorn, Barceloux: Medical Toxicology: Diagnosis and Treatment of Human Poisoning, Elsevier, 1988
- Goldfrank, et al: Goldfrank's Toxicologic Emergencies, Appleton & Lange, 1990
- Haddad, Winchester: Clinical Management of Poisoning and Drug Overdose, WB Saunders, 1990
- Klaassen, et al: Casarett and Doull's Toxicology: The Basic Science of Poisons, MacMillan, 1986
- Rom: Environmental and Occupational Medicine. Little, Brown and Company, 1992

This is not an all inclusive list of references but has been selected as a representative list for use in an emergency department. Most Regional Poison Centers will have many of these references available.

disasters.[78,80] Early involvement of the Health Department, Regional Poison Center, and Environmental Protection Agency may prove helpful in dealing with such concerns. The emergency physician should recognize that these problems may influence the number of patients seeking medical attention hours to days following an incident.

Resource Management

Resource management of equipment, supplies, personnel, and specific antidotes is necessary to provide the greatest good for the greatest number of potential survivors. The hospital command center must assess available resources and forecast future needs. Maintaining supplies may be a considerable problem because of specialized needs. For example, the decontamination procedure requires special supplies that are not stockpiled in most emergency departments. Additionally, a large number of organophosphate poisoned patients will quickly deplete most hospital's stock of atropine and pralidoxime. Locating and transporting additional stockpiles of antidotes may be crucial in a mass casualty incident. The poison center or hospital pharmacy can assist with arrangements to restock antidotes.

Personnel as a resource deserves special consideration. To manage people effectively, personnel should assume duties as similar to their usual daily activities as possible. The number of staff required to enter a potentially contaminated area should be limited.

Protecting resources from secondary contamination is of utmost importance for effective resource management. Contaminated personnel or equipment will not be useful and may need to be replaced. Establish an area (hot zone) for receiving contaminated patients (Fig. 1). This distinct area is necessary to protect hospital staff from toxic exposures, minimize additional exposure to the victim(s), and allow for rapid triage and/or resuscitation of contaminated victims. The hot zone is a clearly marked, secured area with limited access that contains resuscitation equipment. If the hot zone is within the hospital, remove all nonessential equipment and line the floors with heavy plastic.

Security officers play a vital role in a Haz-Mat incident. A single entrance must be established for patients to enter the hospital to prevent contamination of areas outside the hot zone. Well-meaning volunteers may cause secondary contamination and risk the safety of others. It is essential to control volunteers by securing a perimeter and limiting access to the hot zone.

Personal Protective Equipment

The most important responsibility of anyone involved in the care of Haz-Mat victims is self-protection.[76] One method of providing self-protection is to wear adequate personal protective equipment (PPE).[76] The physician in charge of triage and resuscitation teams must decide the appropriate protective equipment to wear before receiving patients. The medical team's level of protection must always be consistent with the contamination of the victim and must be donned before patient care is given. Training is essential before anyone attempts to use specialized personal protective equipment, because improper use may result in injury.[2]

Vapors or fumes from contamination may produce toxicity in hospital staff, especially if respiratory protective equipment is not worn and the room's ventilation is shut off to the outside. Surgical masks do not protect from toxic gases,

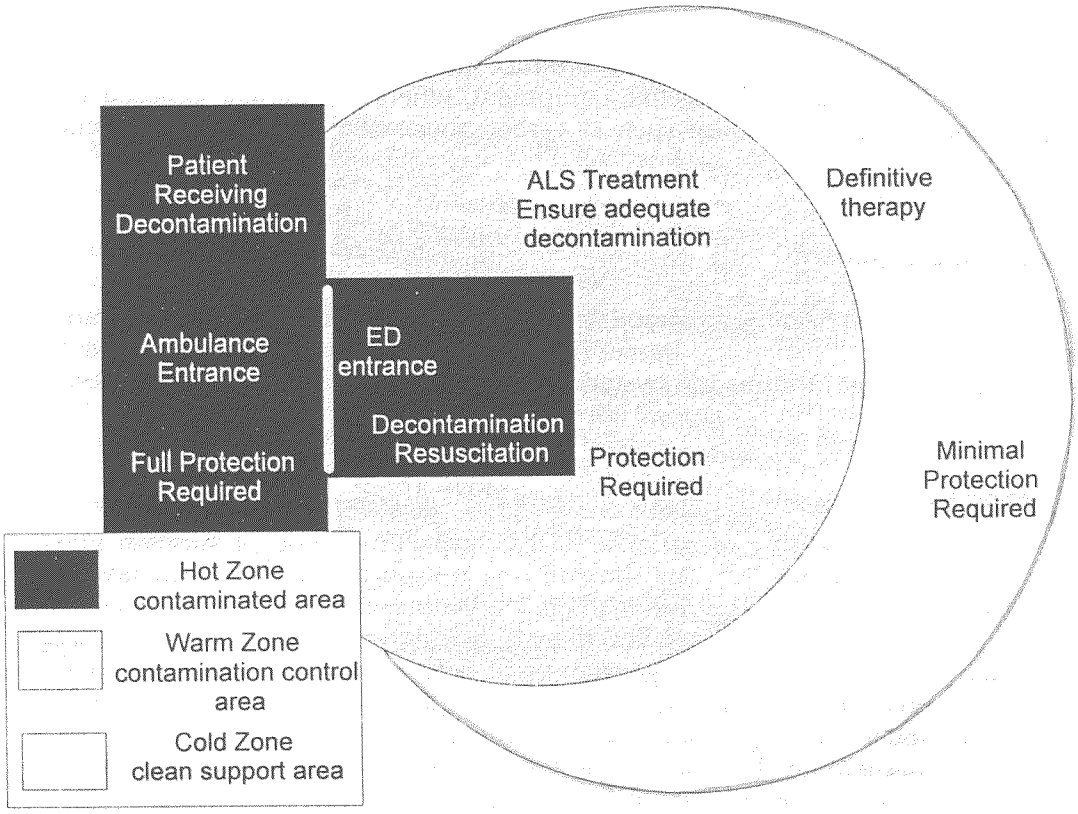

Figure 1. Layout of an emergency department with contaminated "hot zone" clearly defined. Support areas are intended to control spread of contamination into the hospital. All patients, personnel, and equipment moving from "hot zone" *must* be decontaminated.

vapors, or fumes, and specialized respiratory equipment is impractical for most hospitals. Self-contained breathing apparatus (SCBA) is probably unnecessary if patient decontamination occurs outside the hospital. Patients with noticeable chemical odors should remain outside the ED until properly decontaminated Inadequately protected paramedics transporting patients to the ED act as the "miner's canary." A paramedic's lack of symptoms after prolonged contact with a patient in the back of an ambulance suggests toxic fumes are not present or their concentrations are so low that respiratory protection is probably unnecessary. If a paramedic becomes symptomatic during transport, then the patient should not be allowed into the ED until properly decontaminated. These concepts are not foolproof because some highly toxic chemicals are odorless or may cause olfactory fatigue (e.g., hydrogen sulfide) and others may cause delayed effects.

Recommended protective equipment for decontamination and resuscitation team members includes chemical resistant clothing (e.g., Tyvek, the DuPont Company, Wilmington, DE) with built-in hood and boots, at least two layers of gloves (e.g., surgical and nitrile) taped at the sleeve, protective eyewear, and respiratory protection.[2, 14] No consensus exists for the minimum level of protection required for hospital decontamination, especially with regard to respiratory protection. Selecting the appropriate protective equipment truly depends on the specific toxin identified. For example, a patient contaminated with a strong corrosive such as hydrofluoric acid should be handled with splash protective equipment (chemical resistant clothing, gloves, and eye protection). A highly toxic