Methods for Assessing and Reducing Injury from Chemical Accidents
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13 *Planning for the Emergency Medical Service Response to Chemical Disaster*

Jiri Pokorny, Vladimir Dolezal and Erik K. Noji

13.1 INTRODUCTION

Emergency Medical Services (EMS) refers to that component of the medical care system which offers medical aid outside of the hospital setting to seriously ill or injured persons (also referred to as pre-hospital medical care) (Kulling, 1984). An emergency medical service system, on the other hand, describes the entire continuum of acute care provided to patients from beginning to end, and how the various components of the system are integrated. The components of an EMS system include: (a) the bystander who responds to the patient's initial call for help; (*b*) the care that the patient receives from rescue and paramedical personnel; (*c*) the communication system that links pre-hospital and hospital personnel; (*d*) the means of patient transportation; and (*e*) the patient's acute management in the hospital emergency department and intensive care unit settings. The sophistication and degree of development of pre-hospital emergency medical services varies greatly from country to country and even within individual countries. Although most of the activities of an EMS system are geared to the everyday care of the individual patient, the system must also be prepared to cope with mass casualties following natural and man-made disasters.

Hazardous materials (those constituting a threat to people, animals, plants or environment) are nearly ubiquitous in the industrial setting. Often, the diagnosis of occupational poisoning requires a careful history and a high index of suspicion. Hazardous material emergencies usually involve unknown substances or unknown concentrations of chemicals that have been identified as highly dangerous.

Many accidents or disaster situations become less dangerous as time goes on, but this is not true of situations involving hazardous materials (Leonard, 1986). As long as any hazardous chemical is present in any form, whether toxic, flammable, or explosive, that material continues to pose a threat to the lives and health of the population.

13.2 TYPES OF INJURIES CAUSED BY HAZARDOUS MATERIALS

1. Thermal, including electrical and other burns.
2. Radiation-related injuries; important factors are type of radiation, distance of patient to source, time of exposure, degree of shielding.
3. Asphyxiation, i.e. toxic gases which can displace oxygen in the environment causing hypoxia, or airway or pulmonary irritation leading to asphyxiation.
4. Toxic chemicals, especially pesticides, organophosphates, and irritants.
5. Biologic agents: AIDS, hepatitis, other infectious diseases.

EMS personnel should note and record any smell noted by patients or rescuers. Colours of liquids, powders and gases may be important pieces of information. In the unknown exposure, the examiner should search for diagnostic or suggestive signs during the physical examination. The two most common routes of injury from hazardous chemicals are skin contact and inhalation (Burton and Bayer, 1985). If the injury is from smoke inhalation, knowledge of what was burning may aid in the diagnosis. Burning plastics may release hydrogen halides. Incomplete combustion produces carbon monoxide. Phosgene is released from the burning of carbon tetrachloride, trichloroethylene and other halogenated hydrocarbons. Acrolein is released from burning wood, animals fats and other organics.

There are very few specific physical findings unique to patients suffering from a toxic exposure. Suggestive findings include fever that may occur from metal fume intoxication; copious secretions accompanying organophosphate insecticide poisoning; flame-shaped retinal haemorrhages in normotensive people from carbon monoxide; rhinitis, conjunctivitis, and pharyngitis seen in irritant gas injury; rales and dyspnoea in pulmonary injury; wheezing from pulmonary sensitizers such as grain dust and polyvinyl chloride. Pain out of proportion to the injury in cutaneous exposure should raise the possibility of hydrofluoric acid contact.

13.3 CHEMICAL DISASTER PLANNING

A disaster refers to any situation that overwhelms the community's ability to respond (Beinin, 1985). According to the World Health Organization, a disaster may also be classified as focal, local, regional, national and international (Pocchiari and Silano, 1985). A focal chemical disaster accident is one that should be well within the means of plant personnel and the adjacent emergency medical services to cope with without calling for outside assistance. The scope of the chemical disaster, however, may extend beyond the confines of the plant area itself to affect populations in the local district or even province (Kulling, 1984). In some cases, such as Chernobyl, the effects may actually extend beyond the borders of the nation.

In such cases all technical and medical means available must be activated for coping with the disaster. The more extensive the accident or disaster, the more need there is for an organized and professional emergency medical response. This may require calling upon the assistance of the Civil Protection and Army Medical Services. International medical assistance may be indicated when local and national resources prove to be inadequate for responding to the demands of disaster relief. International aid should be initiated only at the request of the government of the affected country. The most important international agencies for coordinating this response are the League of Red Cross Societies, the Office of the UN Disaster Relief Coordinator (UNDRO) and the World Health Organization – all located in Geneva, Switzerland.

The most important requirement of chemical disaster management is rapid and accurate access to information (US EPA, 1985; Leonard, 1986). For example, if one knew immediately that a truck was leaking a particular poisonous gas, rescuers would be advised not to approach the site without respiratory and skin protection (Chemical Emergencies, 1986). If the local emergency room knew that all victims incurred organophosphate insecticide exposure, they could arrange for adequate supplies of the antidote, atropine. When many of these questions cannot be answered in a timely manner, a potential disaster can turn into a true disaster (Tierney, 1980).

To a certain degree, the impact of chemical disasters can be predicted, and the medical response planned for (Chemical Emergencies, 1986; Kulling and Wallenstrom, 1986). Managers of a chemical plant or of facilities where crude oil or combustible plastics are stored should be aware of the dangers which exist from the spreading of toxic gases, vapours or dusts for workers as well as for the adjacent population. The probable direction that such contamination will follow, the geographic area of contamination, the duration of contamination, the specific character of expected intoxication and the exposure risk for the population may be predicted from computer-derived mathematical models (e.g. the BINIT approach by Dolezal, 1985). From such computer models, the impact of chemical disasters on the local population can be predicted and this information utilized by local disaster planners. The development of a well-organized and drilled disaster plan is essential to the successful response of the health sector to such chemical incidents.

A chemical factory's disaster plan should provide responsible authorities with enough data and information to allow them to accomplish the following (Grunderloy and Stone, 1981):

1. Rapidly assess the type and quantity of toxic chemical leakage.
2. Provide early and sufficient warning to workers allowing them to take appropriate safety measures.
3. Rapidly access appropriately trained, and equipped, police, rescue and EMS personnel.
4. Control or halt further escape of hazardous materials.

5. Quickly evacuate injured and potentially exposed persons from the contaminated area.

The plant's disaster plan should also include guidelines for the education and preparation of the plant's workers and local population in the event of a release of toxic substances into the environment. This would include education as to the nature of potentially hazardous materials present in the plant, recognition of signs and symptoms of exposure and effective safety measures. Hopefully, local health care providers (paramedics, emergency nurses and physicians) and rescue personnel would be well versed in the potential dangers posed by a release of hazardous materials from the local factory. The training of local health personnel should be included in the plant's disaster plan and their familiarity with hazardous materials management ensured by frequent hazardous materials disaster drills (Isman, 1982; Industrial Protection Guide, 1985).

Practice during such disaster drills helps police, fire and EMS personnel understand who is to take charge, and the various lines of authority and responsibility. Preplanning and practice drills are essential to avoid potential time-wasting interpersonal and interagency conflicts during an actual disaster. Preplanning for disasters also assures that disaster personnel are familiar with all relevant community resources (Leonard, 1986; National Response Team, 1987). For example, each local hospital's bed capacity and average bed availability should be known. Traffic patterns and location of major roadways also need to be known in advance. Enlisting the active support of all agencies potentially involved in chemical disasters and instituting several mock disasters or disaster drills can point out inefficiencies in the plan and areas in which inter-agency communication is lacking (Kulling and Wallenstrom, 1986).

Preparation for hazardous chemical disasters should also be an integral part of local hospital and community disaster plans. Such plans should detail specific actions and responsibilities of various community services in the event of a crisis situation (MacLeod, 1985). Before any community begins to develop hazardous materials plans, the first step is to determine which materials are most likely to be involved, the possible types of contamination and information regarding specific measures in the event of a hazardous materials incident. Such measures, however, must be realistically tailored to the resources available in a given country or region (Kulling, 1984; Leonard, 1986).

The planners should identify those industries that manufacture or use chemicals (including compressed gas), identify the relevant chemicals, and determine which ones are shipped in or out of, or are stored on, the premises. The planners should not overlook research laboratories including those in universities, since many of them deal with a great variety and quantity of chemicals (Grunderloy and Stone, 1981). Other areas in which hazardous materials are likely to be found include:

1. *Transportation* What type of transportation routes for hazardous ma-

terials exist in the EMS response area: airports, major pipelines, railroad, major highways? What would happen in the event of a major derailment, fire, or explosion (Tierney, 1980; US Congress, 1986)?

2. *Fixed facilities* Even a benign-looking office building or store might hold potential dangers. For example, jewellery stores use cyanide. Among hazardous materials used in hospitals are anaesthetic gases, sterilizing gases, radioactive materials, biologicals and chemicals.

Community and hospital level plans should include local sources of expertise that can be immediately contacted for technical assistance. Such sources may include a toxicologist, a pharmacologist, an industrial hygienist, an industrial medicine specialist, testing laboratories and chemists. Although usually thought of only in regard to poisonings and overdoses with medications and illicit drugs, local poison information centres may prove to be an extremely useful source of information regarding the management of toxic chemical accidents (Kulling, 1984; Leonard, 1986). (See Appendix in Part A of this volume for access to poison control centres and other information resources.) Plans should also include potential sources of specialized equipment that may be needed for a given hazard, e.g. heavy equipment, oxygen, chemicals for 'neutralization', protective gear and transportation vehicles. This equipment must be located centrally in the community, and its location must be known to all responders.

To coordinate more effectively the medical response to chemical disasters, it may be desirable to establish a committee with representation from the agency responsible for emergency medical services (e.g. fire department), the local health department, the Red Cross and local hospitals. The ideal person to chair this committee would be a physician specializing in emergency or critical care. This committee should be authorized to develop the health component of the community's chemical disaster plan as well as to be responsible for the coordination of all activities related to preparedness and response of EMS personnel to a hazardous materials incident.

In summary, any effective programme for controlling toxic industrial exposures needs to:

- identify potentially hazardous materials in use;
- teach personnel how to use protective equipment;
- monitor the workplace to ensure that toxic limits are not exceeded;
- train personnel to respond to leaks, spills or accidents involving toxic materials;
- monitor employees for signs of occupational poisoning;
- dispose of toxic wastes safely.

An effective chemical accident plan has the following characteristics (Leonard, 1986):

1. It specifies who is in charge.
2. It describes the functions that must be performed.
3. It specifies who is in charge of each function.
4. It identifies resources available for response.
5. It facilitates coordination between responding parties.
6. It is known and understood by all potential responding personnel and government officials.

13.4 MEDICAL MANAGEMENT OF CHEMICAL DISASTERS

Basic medical measures in a large-scale hazardous materials accident do not differ substantially from life-saving measures in other mass casualty-producing incidents (Dolezal and Pokorny, this volume, Chapter 6). Initial attention to patency of airway, ensuring adequate ventilation and circulation continues to remain of paramount importance. There are several important differences, however, that occur in disasters involving hazardous materials (Doyle *et al.*, 1983). These include the need for effective decontamination of victims and the other is the need for effective safety measures on the part of rescue personnel. This will require intensive education on the part of health personnel potentially responding to a hazardous materials incident. Ideally, first responders to a hazardous materials incident should have the following equipment (Industrial Protection Guide, 1985; Burton and Bayer, 1985):

1. Self-contained breathing devices or filter masks are necessary when toxic gases or particulates are encountered (Chemical Emergencies, 1986).
2. Impermeable protective clothing such as suits, gloves, boots and helmets are necessary in handling certain very toxic materials.
3. Showers, or means of rapid decontamination, and large quantities of fluid for immediate eye irrigation.

Selecting the proper equipment almost always depends on the situation. Factors include the type of contamination and maximum concentration, the expected length of exposure and the likelihood of oxygen deficiency. Hazardous material incidents involving unidentified chemicals or unknown concentrations of chemicals that are known to be highly toxic require maximum levels of personal protection. This usually means a positive-pressure, self-contained breathing apparatus and a total-encapsulating suit (Burton and Bayer, 1985).

EMS and rescue personnel must also be very familiar with what to expect from conditions resulting in a chemical disaster in their area. This will require knowledge of what chemicals are produced in that particular region. For example, many hazardous materials may not be toxic *per se* but may present the danger of fire or explosion if not carefully handled. Polyurethane is an example of a compound which is non-toxic unless burned, in which case cyanide gas may be released (Burton and Bayer, 1985; Leonard, 1986). If the composition of building materials is not known and there are victims overcome by smoke, they should be treated for carbon monoxide poisoning and possible toxic gas inhalation.

The most important basic for all rescuers to keep in mind and to practise even during drills is self-preservation. Rescuers may be overcome by toxic fumes if they rush to the site without adequate protective clothing and equipment. Injured or dead rescuers add to the disaster and do not help injured casualties. Assessment of fire, explosion, and radiation potential should occur as early as possible. Such a hazard assessment in imperative before attempting to rescue and triage casualties (Isman, 1982; Industrial Protection Guide, 1985).

Personnel trained in the use of self-contained breathing apparatus (usually firefighters) should be responsible for effecting rescue and decontamination and for bringing patients out of the contaminated area. Health personnel should be prohibited from entering a toxic area until permission has been granted by the person in charge of rescue and site decontamination. Before such permission is granted, the EMS team should provide medical advice to the rescue team via the radio. Due to the danger to health personnel from the toxic substance, it is extremely important for paramedics to obtain information from the police or the rescue staff as to what areas have been potentially contaminated before arriving at the scene. Safe perimeters for containment, decontamination, triage and treatment must be established at the outset, with all approaches and movement occurring upwind from a chemical spill. Except for basic resuscitative measures (opening airways, artificial ventilation and compressions and dressing for haemorrhage) all medical care should take place outside the contaminated area (Doyle *et al.*, 1983; Leonard, 1986).

With the rescuers in appropriate protective gear, the patient(s) are moved from the immediate contaminated area. Care is taken to protect the cervical spine if trauma has occurred. If respiratory protection is needed for rescuers, it may be dangerous to use an open ambubag system to assist the ventilation of a patient since more toxic fumes may be bagged into the victim's lungs. Therefore, the ambubag system must be supplemented with a protective filter screwed on the air entry valve of the self-inflating bag. If artificial ventilations are required, a demand valve should probably be used.

The general principle in managing cutaneous injury is to remove clothing and copiously wash all exposed areas with water or other decontamination solutions if available. A rare exception to this rule would be exposure to agents that react violently with water (e.g. the chemical may ignite, explode, or produce toxic fumes with water) such as chlorosulphonic acid, titanium tetrachloride or calcium oxide. Another consideration with this rule would be agents insoluble in water such as phosphorus.

Rescue personnel should not overlook other hazards. If the scene involves derailed railway carriages, wrecked and burning trucks, fire, or explosions in factories, it is easy to concentrate so intently on the hazardous materials involved that the more mundane hazards presented (Isman, 1982; Industrial Protection Guide, 1985) by these situations are overlooked.

Lastly, vehicles and the environment should be protected from hazards. Attempt to ensure the least contamination of vehicles with chemicals by decontamination in the field if possible and protection on instruments and equipment with barriers of plastic or paper.

EMS personnel and hospitals in the vicinity of chemical plants must keep in stock sufficient amounts of medications (e.g. antidotes such as methylene blue for methaemoglobinaemia resulting from aniline dye intoxication). This does not mean that all hospitals in the region must maintain large stocks of rarely used antidotes. For example, in Stockholm, only certain predesignated hospitals keep emergency stores of antidotes (Kulling and Wallenstrom, 1986; Kulling, 1984). If chemicals with the potential for lung injury (e.g. irritant gases) or hypoxia (e.g. carbon monoxide) are produced in the community, it is important that sufficient amounts of stored oxygen and inhalation therapy systems are available. The experience of Bhopal has shown clearly the importance of some type of continuous positive pressure system in patients with chemical pneumonitis resulting from methyl isocyanate (Lorin and Kulling, 1986). It is felt that more people could have been saved if oxygen, which was available in sufficient amount, had been administered through some type of continuous positive pressure system (Safar, 1986). An inexpensive system of continuous positive pressure breathing and ventilation is available from Ambu Copenhagen Equipment. Moreover, sufficient materials for administration of copious eye irrigation in the event of ocular exposure, and for gastric lavage in the event of ingestion of toxic chemicals must also be readily available.

Although specific recommendations would depend on local conditions and needs, it is probably important that local emergency medical services and hospitals be prepared to offer medical treatment following exposure to the following chemicals (Kulling and Wallenstrom, 1986; Kulling, 1984):

> Acids, acrolein, alkalis, ammonia, arsine gas, carbon monoxide, chlorine, cyanide, formalin, formaldehyde, hydrocyanic acid, hydrofluoric acid, hydrogen sulphide gas, irritant gases, heavy metals (e.g. lead, mercury, arsenic), metallic and inorganic compounds, hydrocarbons, nitrites, nitrates (methaemoglobinaemia), organophosphate and carbamate compounds (e.g. pesticides), phenols and phosphorus (both yellow and white), phosphine gas, phosgene gases, and sulphuric acid mist.

As mentioned previously, field stabilization of casualties, and initiation of transport to hospitals must take place outside of the contaminated zone. It is imperative that adequate communication between incident site and medical control site (usually a hospital) be maintained and that the receiving health care facility be adequately forewarned that it will be receiving chemically contaminated patients. Important information to convey includes: number of victims, chemical agent(s) involved, the circumstances underlying the exposure, the extent of the exposure, and therapeutic measures rendered at the scene and *en* *route* to the hospital (Burton and Bayer, 1985; Leonard, 1986; Doyle *et al.*, 1983). Arrangements for treatment at the hospital should be initiated immediately upon such notification. This could include formal provisions for decontamination, mobilizing oxygen tanks and masks for treatment of carbon monoxide poisoning, or obtaining burn linens for victims injured in an explosion.

Ideally, patients contaminated with hazardous chemicals should be brought initially to a special, pre-designated decontamination suite containing a shower with a container to hold drainage water. Rescuers and victims should remove all clothing. This should be bagged and discarded safely. Under no circumstances should undecontaminated patients be brought into regular patient care areas due to the danger of contaminating other patients, hospital staff and equipment. Remember to irrigate eyes and skin for dermal decontamination and to give 100% 0_2 for inhalation exposure. Hospital emergency departments must close off the air systems to rooms in which contaminated patients are taken so toxic products do not get into the ventilation system and circulate to other parts of the hospital. As with rescue personnel, hospital staff should also be protected. This includes gowns, gloves, masks and occasionally self-contained breathing devices. After rescuers and victims are thoroughly rinsed, they may leave the decontamination area and enter the emergency department proper for definitive care. Hospital personnel should leave their gowns, gloves, etc., in the contaminated area (Doyle *et al.*, 1983).

Hospitals in the vicinity of major chemical industries or major transportation routes should already be aware of the possibility of hazardous chemical accidents and it is imperative that they be prepared to effectively manage situations involving many persons contaminated with hazardous chemicals (MacLeod, 1985). It is also important that emergency and critical care physicians be knowledgeable regarding the clinical manifestations and treatment of certain toxic chemicals that workers and other members of the population may be exposed to in their community.

13.5 CONCLUSIONS

1. Every community in which chemical industries are located should have access to specialists with expertise in emergency medicine. Such a specialist in emergency and/or critical care medicine should be prepared to treat patients with chemical/toxic exposure, as well as blast and burn injuries (Pokorny, 1985).
2. All chemical plants or facilities in which toxic chemicals have the potential to be accidentally released into the environment should have detailed disaster contingency plans. Such a plan should include specific data on toxicity of chemicals produced, clinical manifestations, treatment, as well as safety instructions to employees, means of safely evacuating the plant and

mechanisms for rapidly accessing the local EMS, policy and Civil Protection agencies (US EPA, 1985; Chemical Emergencies, 1986; Leonard, 1986).

3. A specialist in emergency care, or a physician with acute care experience would ideally be appointed to chair a committee composed of specialists in toxicology, environmental health, internal medicine, anaesthesiology, critical care, traumatology/surgery, chemistry and chemical technology.
4. Every health department should be informed about preventive or protective programmes in order to avoid diseases induced by the escape of toxic chemicals in or outside the chemical plant (US EPA, 1985; National Response Team, 1987). Specific therapeutic measures including antidotes, oxygen inhalation therapy and gas masks should be available to the population at risk.
5. Both state and local health departments (hospitals, policlinics) in the vicinity of a chemical plant should initiate or work cooperatively with the management of the plant to conduct drills simulating chemical emergencies (National Response Team, 1987; MacLeod, 1985). Through such as exercise, physicians, paramedics as well as other health personnel could learn a great deal about disaster management. The leading role in these activities belongs to the EMS. The disaster plan of the EMS should be oriented in detail to counteract effectively the mass casualties in chemical emergency.
6. Every health department responsible for a territory with a chemical plant should develop a chemical emergency response plan for the health aspects of a chemical accident. The plan should encompass the timely alert of the emergency from the plant, the overall evacuation from the endangered zone and special procedures for specific groups of society, such as newborns, renal dialysis patients, patients on special medications and particularly hospitalized, institutionalized, or home-bound patients. A suggested sequence for triage of hospital patients is maternity, pediatrics, neonates, medical/surgical, intermediate care and intensive care patients.
7. Injured patients should be collected and triaged at a safe place nearby, but outside of the contaminated zone. Initial medical care may be accomplished by paramedics and emergency physicians if necessary. In mass-casualty situations, priority of treatment, that is triage, depends on the degree of the patient's immediate life threat: (Doyle *et al.*, 1983)

   (a) First priority patients include those with respiratory failure or insufficiency (e.g. airway obstruction secondary to laryngeal oedema, impaired ventilation or oxygenation due to chemical pneumonitis).
   (b) Second priority patients include those with circulatory failure or insufficiency (e.g. severe haemorrhage).
   (c) Third priority patients include those with severe burns.
   (d) Fourth priority patients includes all other patients.

   Triage serves as a valuable tool for determining priorities for offering emergency medical aid – an important concept when resources are scarce in relation to demands. Once patients have been adequately stabilized in the field, evacuation to hospitals can then commence – hopefully with equitable distribution of patients in order to avoid overload of the nearest facility.

8. Therapeutic and decontamination measures cannot be generalized, but depend to a great extent on the specific chemical exposure involved. For example, in the case of acute chemical pneumonitis secondary to certain irritant gases, patients may benefit greatly from the early institution of effective inhalational oxygen therapy (e.g. Continuous Positive Airway Pressure system). Although specific antidotes are quite rare, it is important that such drugs be administered as rapidly as possible in order for them to benefit the patient (e.g. oxygen for carbon monoxide intoxication, sodium nitrite for cyanide poisoning and chelating agents for heavy metals).
9. Unlike trauma, with chemical exposure a large number of casualties may have a single system injury, such as respiratory injury (Leonard, 1986). If the emergency department receives large numbers of victims who all have an identical injury, the resources needed to treat that one injury may be depleted. For this reason, carefully selected medical equipment should be available and ready to use in the stores of the local EMS system, health departments or Civil Protection organizations if possible. Examples of such equipment include:

   Oxygen
   Inhalation devices (e.g. nasal prongs, face-masks/CPAP system)
   Selected antidotes
   Cardiotonics
   Circulatory stimulatory drugs
   Infusion solutions
   Infusion sets (i.e. needles, syringes)
   Dressings.

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