Disasters Produced by Natural Phenomena

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Objectives

- Explain the health-related and economic impacts of natural disasters.
- Identify common types of natural disasters and the injuries specific to each.
- Outline general aspects of managing casualties after a natural disaster.
- Discuss the intensivist's role after a natural disaster.
- Describe the management of crush injuries.

Case Study

Sixteen hours after an earthquake, a 35-year-old male is found trapped under his home. His left lower extremity is compressed from the mid-thigh down. Rescuers are preparing to extricate him from the rubble.

- What kind of secondary injury is the man most likely to develop?
- What is the most important therapeutic maneuver that should take place prior to extrication?
- To what other injury is the pathophysiology of crush injury mostly closely related?

I. INTRODUCTION

Disasters produced by natural phenomena are sudden ecological events of sufficient magnitude to require external assistance. In recent years, these events have been affecting increasing numbers of people throughout the world. Since 2000, an average of 400 natural disasters a year have occurred worldwide, which is close to twice the occurrence in the 1980s and early 1990s. The chaos that accompanied Hurricane Katrina in 2005 illustrates how these phenomena can affect even the most developed societies. Moreover, a natural disaster may precipitate a serious technological catastrophe by damaging nuclear power plants, buildings that house dangerous biological or chemical products, dams, or hydrocarbon-storage areas, thus becoming a natural and technological disaster.

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> *From 1991 to 2005, 3,470,162,961 people were affected by natural disasters; 960,502 people were killed; and a cost of $1,192.5 billion has been attributed to disasters produced by natural phenomena.*
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Prevention of disasters through preparedness has been a priority of donor agencies, implementing agencies, and affected countries. To that end, collection of accurate data is paramount. The Centre for Research on the Epidemiology of Disasters, established in 1973 at the Université Catholique de Louvain, Brussels, has been working as a World Health Organization Collaborating Centre since 1980 to collect international data on disasters produced by natural phenomena. Since 1988 the Centre for Research on the Epidemiology of Disasters has also maintained an emergency events database of essential data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to the present. The main goal of the database is to provide data that will ultimately assist in humanitarian actions at national and international levels. The organization's objectives are to provide information for an evidence-based approach to decision making in disasters (ie, vulnerability assessment and priority setting) as well as disaster preparedness. The data are gathered from various sources, including UN agencies, nongovernmental organizations, insurance companies, research institutes, and press agencies.

For a disaster to be entered into the database at least 1 of the following criteria must be fulfilled: 10 or more people died, 100 people were affected, a state of emergency was declared, or a call for international assistance was made (see **Table 9-1**). The categories are not exclusive, as 1 phenomenon may provoke another that ultimately leads to a disaster. An example is the 2004 tsunami in Southeast Asia, which was due to a geophysical event that had hydrological consequences. From 2000 to 2007, most disasters were of the hydrological variety, accounting for about 35% of the events.

II. INITIAL INJURIES IN NATURAL DISASTERS

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> *It is possible that the ongoing climate changes attributed to global warming are at least partially responsible for the increase in the incidence of meteorological events.*
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There are a variety of immediate injuries that may occur and that differ according to the type of event. Most, but not all, of such injuries are traumatic and are triaged and treated according to standard evaluation and resuscitation protocols, like those advocated in the American College of Surgeons' Advanced Trauma Life Support program. In addition, it may be necessary to apply principles of mass casualty management (see **Chapter 2**), especially when medical resources are limited. Several more specific diagnostic and treatment considerations are related to each type of natural disaster.

Table 9-1. Classification of Natural Phenomena

Hydrological/Meteorological Examples
Storms: hurricanes, tornadoes, thunderstorms, hail, tropical storms
Floods
Cold waves and heat waves
Drought
Forest fires
Geophysical Examples
Earthquakes
Volcanoes

A. Hydrological/Meteorological Events

Although hurricane and cyclone winds are responsible for much damage, the wind is not the biggest problem: 90% of hurricane fatalities are caused by drowning associated with storm surges. Other causes of death and injury include the collapse of buildings and resultant penetrating trauma from broken glass or wood, blunt trauma from floating debris, and entrapment in mudslides associated with hurricane floods. Many of the severe injuries occur in people who live in mobile homes or who are injured or electrocuted during post-disaster cleanup. Most initial survivors do not require sophisticated medical or surgical care and can be treated as outpatients. A majority suffer from lacerations and penetrating injuries caused by flying glass and other debris, and a few have closed fractures. It is important to be aware that crowded shelters increase the potential for the spread of infectious diseases, especially those transmitted by aerosol and fecal-oral routes. These infections are especially common when sanitary facilities are insufficient and/or the sanitation infrastructure is damaged.

During tornadoes, the leading causes of death are head trauma and crush trauma to the chest and trunk. Fractures, lacerations, and foreign materials (splinters, tar, dirt, etc) embedded in soft tissue are very common injuries. Wounds contaminated with gram-negative organisms found in soil are also common and contribute to postoperative sepsis. However, as the US National Weather Service's detection technology and radar weather-mapping systems improve and more timely warnings are issued, mortality is decreasing even though the number of tornadoes is increasing. There are almost 700 tornadoes in the United States each year, but only about 3% result in casualties and only 4% of all injuries are fatal. Individuals older than 60 years are at 7 times greater risk due to increased susceptibility to injury from mechanical energy (coincident with other trauma statistics), preexisting medical conditions, decreased ability to comprehend and act rapidly when public tornado warnings are issued, and isolated living. The risk of sustaining a serious or fatal injury is 40 times greater for occupants of mobile homes than for people in permanent, single-family homes, and it is 5 times greater for people in cars.

Another meteorological event that may lead to disaster is extremes of temperature. In 2003, a heat wave led to 14,800 deaths in France alone. Heatstroke with cardiovascular collapse, anuria, and rhabdomyolysis were the principal causes of mortality. Cold temperatures are also a cause of morbidity and mortality due to hypothermia and carbon monoxide poisoning in homes with poor ventilation or makeshift heaters.

Drought may often lead to famine. Such long-term disasters are seen in countries like North Korea, where drought as well as hailstorms, floods, and tidal waves destroyed crops and infrastructure, leading to a profound food crisis and higher incidences of malnutrition, disease, and death.

The occurrence of fires close to urban areas leads to significant property loss, as exemplified by the recent fires that occurred in the proximity of both Los Angeles and San Diego, California. Residents were successfully evacuated in those fires, but widespread fires in underdeveloped countries or in areas without resources can result in significant morbidity and mortality.

B. Geophysical Events

A volcanic eruption may result in significant damage. Eruptions may generate tremendous quantities of ash rainout. Buildings have collapsed from the weight of ash accumulating on their roofs, resulting in severe trauma to their occupants. The ash can be very irritating to the eyes (causing, for example, corneal abrasions), the mucous membranes, and the respiratory system. Upper-airway irritation, cough, and bronchospasm are common findings, as is exacerbation of chronic lung conditions. High concentrations of volcanic ash may cause severe tracheal injury, pulmonary edema, and bronchial obstruction, which could lead to death from acute pulmonary injury or suffocation. In the majority of asphyxiated casualties, the ash mixed with mucus forms plugs that obstruct the main airway (trachea and main bronchi). Furthermore, there is a potential for delayed onset of ash-induced mucus hypersecretion and obstructive airway disease.

Volcanic eruptions may also result in suffocation due to inhalation of massive quantities of airborne ash, scalding superheated steam, and surges of lethal gas. Victims rescued from volcano-generated mudflows may suffer from severe dehydration, burns, and eye infections. Primary closure of wounds contaminated by mud and other volcanic material can result in serious complications, including gangrene, osteomyelitis, compartment syndrome, and sepsis, all of which may lead to amputation of the affected limb. If lacerations have not been addressed for more than 6 to 12 hours or appear contaminated, they should be treated by debridement and left open for delayed primary closure after approximately 3 days. Appropriate tetanus prophylaxis should also be administered. Admission of patients with respiratory distress to an intensive care unit is advised.

Hospitals and other healthcare facilities are particularly vulnerable to the damaging effects of earthquakes. The primary cause of death and injury in earthquakes results from the total collapse of buildings that were not designed to withstand earthquakes and were poorly constructed or built of inadequate materials. In severe earthquakes, death may be instantaneous owing to severe crushing injuries of the head or chest, exsanguination from external or internal hemorrhaging, or drowning from earthquake-induced tidal waves (tsunamis). Death may also occur within minutes or hours due to asphyxia, hypovolemic shock, or exposure (eg, hypothermia), or it may be delayed for days and be secondary to dehydration, hypothermia, hyperthermia, crush syndrome, or postoperative sepsis. As in other disasters, the majority of people seeking medical assistance will have minor cuts and bruises, followed by a smaller group suffering from simple fractures that do not require surgery. Less than 4% of people injured by earthquakes require inpatient care. That group will include people with serious multiple fractures or internal injuries, hypothermia, sepsis from wound infections, multiple organ failure, and renal failure secondary to crush syndrome. Crush syndrome, which may be seen in a number of natural disasters, is discussed in detail later in this chapter.

In addition to those who need intensive care, there will be a large number of patients who require acute care for nonsurgical problems such as myocardial infarction, exacerbations of chronic diseases like diabetes and hypertension, respiratory problems from exposure to heavy dust from rubble, and anxiety and other mental problems. As noted previously, the dust produced by buildings crumbling immediately following an earthquake may cause life-threatening asphyxiation and upper-airway obstruction. Fulminant pulmonary edema from dust inhalation may also be a cause of mortality. Asbestos and other particulate matter in the dust may pose both subacute and chronic respiratory hazards to entrapped victims as well as to rescue and cleanup personnel, depending on the characteristics and toxicity of the dust. An example of the delayed effects of dust inhalation in rescue personnel (albeit due to a terrorist attack and not a natural disaster) can be seen in current medical reports of firefighters who worked in and around the World Trade Center in New York City following the September 11, 2001, attack.

When a building collapses, a rapid response is absolutely critical to maximize the victims' chances of survival. The proportion of people found alive declines with the passage of time. More than 90% of survivors are extricated within 24 hours, and more than 90% of mortalities occur prior to extrication. Estimates indicate that within 2 to 6 hours, less than 50% of trapped victims are still alive. Safar reported that 25% to 50% of victims who were injured and died slowly could have been saved if they had immediately received lifesaving first aid (see Suggested Readings).

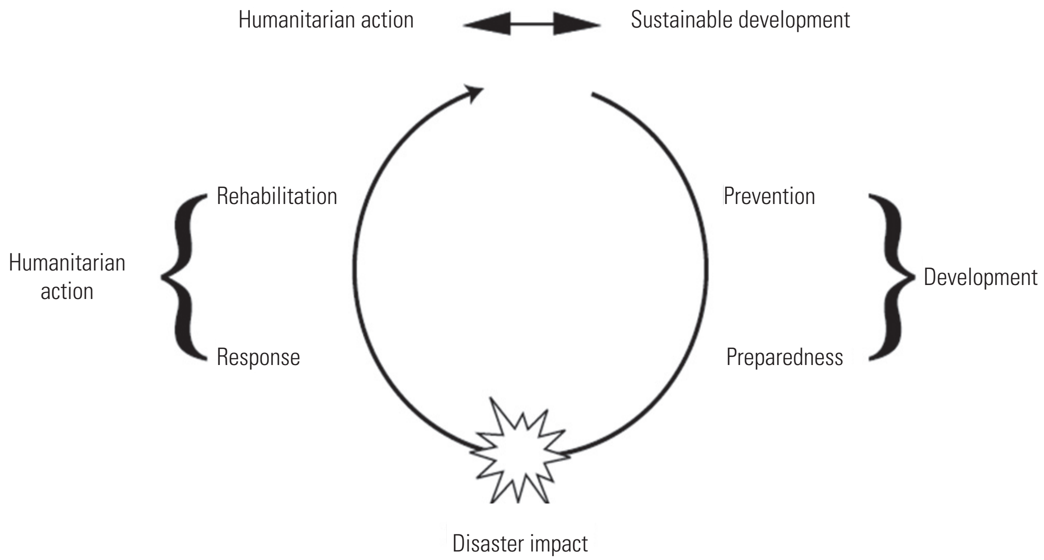
III. THE DISASTER-MANAGEMENT CYCLE AND THE SECOND DISASTER

Different geographic regions are at risk for different kinds of potentially destructive natural phenomena. When a population is particularly vulnerable to a specific type of event, the only way to reduce that vulnerability is to prepare. The disaster-management cycle in **Figure 9-1** summarizes an integrated approach that communities at risk may adopt to prepare for, respond to, and recover from a natural disaster. The right part of the diagram pertains to the need for planners to develop programs for prevention and preparedness before disaster strikes. The left part of the diagram relates to the post-

> **!** *Healthcare decisions made during an emergency are often based on insufficient, nonexistent, or even false information and may result in a second disaster.* **!**

disaster need for humanitarian assistance in the forms of immediate response and rehabilitation. The cycle then repeats. A linear, more detailed version of the risk-management cycle is illustrated in **Figure 9-2**.

Figure 9-1. The Disaster-Management Cycle [a]

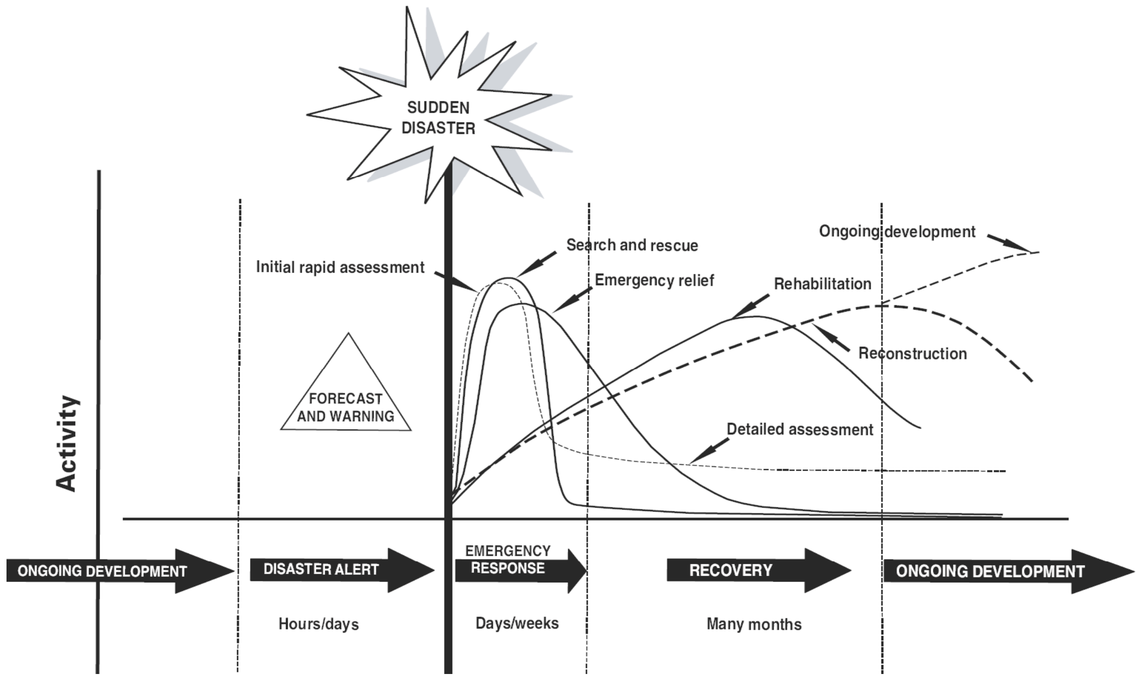


[a] Reprinted with permission from Wisner B, Adams J. *Environmental Health in Emergencies and Disasters: A Practical Guide*. Geneva, Switzerland: WHO Press; 2003:3.

Communities should have an active, up-to-date preparedness program, and in some cases (such as hurricanes), they may receive warning of an impending threat, which will allow further preparation. Immediately following the impact, the planned emergency response begins with a rapid assessment of damage, followed by search and rescue and emergency relief. Unlike the emergency response, which must be swift, the recovery phase lasts many months. During that phase, people's livelihoods are restored, homes and infrastructure are reconstructed, and all events related to the disaster and its aftermath are thoroughly assessed. During the event and afterwards, lessons learned should be identified for use in preparing for future events, and the cycle then resumes. For example, hospitals in the vicinity of both active and dormant volcanoes should be prepared to deal with a sudden influx of casualties with severe burns and lung damage from inhalation of hot ash as well as all other types of trauma common with volcanic eruptions. Earthquake-prone areas should have plans for evacuation to areas resistant to seismic events and the deployment of rapid response rescue teams trained in the management of crush injuries.

Many times healthcare decisions made during an emergency are based on insufficient, nonexistent, or even false information. This is especially likely in unprepared communities and leads to inappropriate, inadequate, or unnecessary medical aid, wasteful consumption of health resources, and counter-effective activities. The result is a second disaster.

Figure 9-2. Disaster-Management Cycle: Details and Timing [a]



[a] Reprinted with permission from Wisner B, Adams J. *Environmental Health in Emergencies and Disasters: A Practical Guide*. Geneva, Switzerland: WHO Press; 2003:19.

IV. PRINCIPLES OF MANAGEMENT IN A NATURAL DISASTER

A variety of healthcare-related issues must be addressed following a disaster generated by a natural phenomenon. They include public health, rescue operations, international assistance, transportation of patients, and provision of critical care.

A. Public Health

Although trauma care dominates the initial emergency response, it is quickly displaced by public health needs. Because public health issues affect clinical interventions and because hospitals may be working in an austere or damaged environment, public health and preventive measures become very important. They include sanitation, disposition of corpses, prophylactic measures, control of vectors, and mental health.

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1. Sanitation

Sanitation relates to the availability of potable water and disposal of excreta and waste. Lack of water constitutes an emergency. Both the availability and the quality of water are important. Additionally, proper management of excreta and solid waste is crucial to prevent, or at least minimize, oral-, fecal-, and vector-related transmission of disease.

2. Disposition of Corpses

As corpses do not cause epidemics, survivors are the priority. However, it is important to identify and tag cadavers and issue death certificates as soon as possible. Early identification of corpses is essential for the emotional well-being of the victims' families and loved ones. The anxiety of uncertainty and fantasies of survival are replaced by concrete grief and the process of accepting the death. Prompt identification and disposal increases survivors' comfort and shields them from the byproducts of bodily decay. If possible, digital photographs may be taken to assist with identification of cadavers, especially when quick disposal is necessary.

3. Prophylactic Measures

There is no need for prophylactic immunization or antibiotics after a natural disaster. Primary care should be resumed as soon as possible, and surveillance of any potential rise in endemic diseases should continue for some time.

4. Disease Vectors

A natural disaster may disrupt disease vectors and increase their ubiquity. Control of vectors that carry or transmit diseases is mandatory and varies by geographic area. For example, mosquito-transmitted diseases such as dengue, malaria, or yellow fever might appear or increase in incidence following a flood.

5. Mental Health

Mental health is of paramount importance to prevent post-traumatic stress disorder. Counseling might not suffice, and pharmacological therapy may be needed.

B. Rescue Operations

Critical care providers should not participate in rescue operations unless they are properly trained. However, even if trained, they play no role unless help is requested. Rescue operations involve many risks, such as drowning, electrocution, entrapment, asphyxia, and contamination (chemical, biological, and radiological). In this environment, scene safety and security take precedence over patient care—a difficult concept for most hospital-based healthcare providers to accept. It is important that people not directly involved in search and rescue avoid becoming victims and taxing an already overburdened system. Instead, individuals wishing to participate may be better utilized in another area of need, typically in the area where they normally work.

C. International Assistance: Field Hospitals and Team Deployment

The development of field hospitals and the deployment of personnel by international assistance agencies are topics of some controversy. The World Health Organization published guidelines related to these topics in 2003. Such costly interventions have the potential to be impediments rather than solutions because they may not meet the needs of the situation and may impede local solutions. If needed and requested, a field hospital and its team may be able to provide advanced trauma care and life support within 48 hours of an event. They may also be able to help with follow-up care for trauma victims and resumption of routine medical care within the 2-week period following the event. The availability of field hospitals and additional personnel may be especially beneficial when a disaster has severely damaged local healthcare facilities (eg, has destroyed intensive care units and operating rooms, essential supplies, equipment, and other resources). In such cases of need, especially during the rehabilitation and reconstruction phases (from 2 months to 2 or more years), a field hospital might serve as a temporary replacement for the damaged health facilities, though it will need to be converted from trauma care to medical/prevention care.

D. Transportation

Because transportation may place patients and transport personnel at undue risk, its necessity must be clear. Challenges include adherence to professional guidelines for the safe transport of critically ill patients (see the Society of Critical Care Medicine's "Guidelines for the inter- and intrahospital transport of critically ill patients"), selection of the correct transportation mode (considering need for speed, specific geography, weather), and the impact of transport on the patient. These become particularly crucial with air rescue and associated atmospheric changes. As a general rule, air transport is used for long distances or in cases where speed is necessary. Air transport may be by fixed wing or helicopters and each mode has advantages and disadvantages. Ground transport is an alternative for shorter distances, provided that the adequate level of care can be provided.

E. Provision of Critical Care

In a disaster, the critical care clinician, if properly trained, may provide care in a primary specialty as 1 member of a multidisciplinary team. The critical care management of the injured patient starts at the scene. (The prehospital assessment and management of patients are discussed in detail elsewhere in this text.) Once a critically ill patient arrives at the facility, the critical care clinician plays an important role. He or she triages, institutes, and monitors patient care based on protocols, and coordinates advanced transport if necessary.

The triage of patients during mass disasters is a difficult task. Ensuring that patients receive the proper level of care when resources are scarce includes the ability and responsibility to assign lower priority to those who will live without treatment and those who will die despite treatment. Difficult medical and ethical considerations are involved in those decisions. Given that critical care physicians are trained in distribution of acutely ill patients to intensive care units, their input can optimize the triage process. They are also very familiar with end-of-life issues. It is mandatory to provide appropriate comfort to patients who will not receive medical treatment and will die of their injuries.

The use of protocols in the intensive care unit has been shown to improve survival. Critical care physicians are familiar with the use of protocols and are capable to assess patients, initiate therapy, and evaluate results. In times of crisis, the use of standardized and simplified protocols that can be applied by providers who have not specialized in critical care can extend the availability of critical services. The development and implementation of such protocols for sepsis, respiratory failure, crush syndrome, and the like also fall into the realm of the critical care practitioner.

V. CRUSH SYNDROME

Patients trapped for several hours or days may develop crush syndrome (CS), which is characterized by hypovolemic shock, hyperkalemia, and fatal cardiac arrhythmias. This can then progress, if not promptly relieved, into rhabdomyolysis and acute renal failure. Reports from the Hanshin-Awaji earthquake in Japan in 1995 noted that casualties were buried under collapsed buildings for an average of almost 7 hours (range, 1-24 hours) and were referred to hospitals from 6 to 250 hours after the event. Of those who arrived within 40 hours, 25% developed renal failure compared to 100% of those who arrived after 40 hours. Additionally, renal failure was strongly associated with massive muscle damage (creatinine phosphokinase >25,000 U/L) and insufficient fluid resuscitation (less than 10,000 mL in 2 days). Prompt and adequate fluid resuscitation is essential to prevent renal failure. These data also highlight other aspects of managing crush syndrome, such as the importance of early release from entrapment, the recognition of a possible crush injury, the rapid institution of appropriate care, and the role of aggressive hydration.

A. Pathophysiology of Crush Syndrome

Alteration in muscle microcirculation leads to hypoperfusion, hypoxic metabolism, and myocyte death. Mechanisms include direct trauma with immediate cell disruption, compression of the muscle group, and vascular compromise with lack of circulation or poor perfusion. The lysed cell releases substances that have toxic effects in the systemic circulation, including but not limited to myoglobin, creatinine phosphokinase, amino acids, histamine, potassium, phosphate, calcium, and lactic acid. These may continue to leak into the body for as long as 60 hours after release of crush injury. Subsequent systemic manifestations of this process include renal failure from myoglobin in the renal tubules; electrolyte anomalies, particularly hyperkalemia with associated cardiac arrhythmias; metabolic acidosis; and hypovolemia. If left unchecked, the process progresses into disseminated intravascular coagulation, acute respiratory distress syndrome, sepsis, multisystem organ failure, and finally death.

B. Management of Crush Syndrome

In entrapped casualties, the release of toxic substances into systemic circulation occurs when the pressure in the muscle group is released and the injured tissues are reperfused. Therefore, the cornerstone of prehospital management is to prevent, or at least to minimize, the impact of the reperfusion injury. In other words, treatment must start prior to decompression. A reason for the development of many reperfusion problems is that the complications are not anticipated. Also, removal of the compressive mass prior to the arrival of medical assistance may result in adverse outcomes and death.

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> *Crush syndrome is potentially identified by the 5 P's: pulseless (with absent capillary refill), pale, painless, poikilothermic (cool and clammy skin), and paralyzed.*
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1. Diagnosis of Crush Syndrome

As a general rule, crush syndrome should be suspected based on 3 criteria: involvement of a large muscle mass, prolonged compression (as little as 1 hour but typically 4-6 hours or more), and signs of a vascular occlusion. A crush injury may be identified by the 5 P's: pulseless (with absent capillary refill), pale, painless, poikilothermic (cool and clammy skin), and paralyzed. Usually, there is absence of pain in the affected region. Additionally, a weak, rapid pulse might indicate the onset of hypovolemic shock, as third spacing occurs in the injured muscle of a patient devoid of fluids. It is absolutely imperative that a patient be assessed before extrication begins. If a crush injury is suspected, appropriate treatment should be initiated prior to extrication, and transfer to a center where advanced care can be provided must be coordinated. Steps should be taken to make sure the rescue team is aware of the importance of treating patients prior to extrication.

2. Aggressive Hydration

It is vital to begin aggressive hydration before extrication. One or 2 large-bore intravenous lines should be placed, and 1 to 2 L of normal saline should be provided before the crush object is removed. If extrication is prolonged, infuse normal saline at 1 to 1.5 L/h or at 10 to 15 mL/kg/h. Patients under 12 years of age, the elderly, and those with a history of renal insufficiency or failure should be given only 500-mL boluses followed by repeated checking of lung sounds. Ideally, cardiac monitoring should be instituted simultaneously because lethal cardiac arrhythmias and hypotension might develop at the time of extrication.

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After extrication, fluids should be changed to hypotonic saline, and a high urine output should be maintained (>3-4 mL/kg/h or more than 300 mL/h). Fluid requirements might be as high as 6 to 12 L/day because fluid accumulation in muscle may account for up to 4 L/day. This aggressive hydration continues until clinical or biochemical evidence of myoglobinuria disappears. This usually occurs by day 3. Fluid status is closely monitored, ideally with a central venous pressure catheter. In the absence of central venous pressure monitoring and if hypervolemia is suspected clinically, the fluids may be decreased to half with frequent reassessment of volume status. Oliguria may require dialysis (discussed later in this chapter). Mannitol, as a free radical scavenger, may be added to assist diuresis and provide kidney protection in the face of decreased compartment pressures. Additionally, the use of sodium bicarbonate for urine alkalinization has been proposed as a means of preventing myoglobin nephrotoxicity. Its efficacy has not been conclusively demonstrated.

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> *Fatal hyperkalemia may occur immediately after the release of compression, during transport, or secondary to acute renal failure.*
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3. Electrolyte Anomalies

Electrolyte anomalies are also frequent after extrication. Fatal hyperkalemia is a common cause of death that may occur right after the release of compression, during transport, or secondary to acute renal failure. Hyperkalemia should be suspected if entrapment lasted longer than 4 hours and an electrocardiogram demonstrates peaked T waves, absent P waves, or widened QRS complexes. If present, the provision of sodium polystyrene sulfonate prior to transport should be considered. One gram of calcium chloride slowly administered intravenously stabilizes the myocyte cardiac membrane and reduces the likelihood of arrhythmias. Sodium bicarbonate is also helpful in decreasing the plasma pH and therefore favors the movement of potassium into the cells. Although hypocalcemia is a common finding in rhabdomyolysis, it is rarely symptomatic when present alone and therefore does not necessitate treatment with calcium salts. Other electrolyte anomalies, such as hyperphosphatemia, hypernatremia, and hyponatremia, may be present and should be treated accordingly.

Dialysis should be considered as a lifesaving procedure in cases of oliguria, anuria, and volume overload or of biochemical abnormalities such as uremia, acidemia, and hyperkalemia. Prophylactic dialysis for patients at high risk of hyperkalemia should be considered. In most cases requiring this intervention, the average duration is 13 to 18 days. All types of dialysis may be considered, but each has advantages and disadvantages. For example, intermittent hemodialysis in short daily courses will prevent hyperkalemia but requires technical support, electricity, trained personnel, and tap water supply, all of which may be affected by the disaster. Continuous renal replacement is an excellent method of gradually removing fluids and solute, but its logistical problems are similar to those of hemodialysis. It also carries the risk of bleeding due to anticoagulation. Peritoneal dialysis is simple and does not necessitate electricity or tap water, but it requires sterile dialysate and thus may be impractical in a field environment that may be unsanitary. Peritoneal dialysis is also contraindicated in patients with suspected abdominal injuries such as those sustained with crush.

Key Points

DISASTERS PRODUCED BY NATURAL PHENOMENA

- Natural disasters exceed all other forms of disaster in terms of mortality, number of affected people, and economic impact worldwide.
- Different geographic regions are vulnerable to different kinds of potentially destructive natural phenomena, and the immediate injuries that may occur differ according to the type of phenomenon.
- When a population is particularly vulnerable to a specific type of event, the only way to reduce that vulnerability is to prepare.
- The health-related issues that emergency workers may face during a disaster include sanitation, rescue missions, international aid in the form of field hospitals or additional personnel, transportation of victims, and provision of critical care. All may affect the individual and the ability to provide care.
- In a disaster, intensivists and others trained in critical care may participate by providing care in their own primary specialties, by helping in the triage of victims, or by implementing intensive-care-driven protocols. Only providers trained in rescue operations should practice in the prehospital environment, and only when their services are requested.
- Crush injury is common in many natural disasters, but it is frequently underrecognized and undertreated, which results in preventable deaths.
- Key issues in the management of crush injuries are early recognition, institution of aggressive hydration prior to extrication, prevention and treatment of hyperkalemia, and rapid transport to a center where advanced care can be provided.

Suggested Readings

Abbott D. Disaster public health considerations. *Prehosp Disaster Med*. 2000;15(4):158-166.

Argaud L, Ferry T, Le QH, et al. Short- and long-term outcomes of heatstroke following the 2003 heat wave in Lyon, France. *Arch Intern Med*. 2007;12(16):2177-2183.

Atwater C. Cardiac arrest after crush injury. *Br Med J*. 1983;287:533.

Better OS, Stein JH. Early management of shock and prophylaxis of acute renal failure in traumatic rhabdomyolysis. *N Eng J Med*. 1990;322(12):825-829.

Galea S, Tracy M, Norris F, Coffey SF. Financial and social circumstances and the incidence and course of PTSD in Mississippi during the first two years after Hurricane Katrina. *J Trauma Stress*. 2008;21(4):357-368

Gonzalez D. Crush syndrome. *Crit Care Med*. 2005;33(suppl 1):S34-S41.

Guidelines Committee of the American College of Critical Care Medicine, Society of Critical Care Medicine, American Association of Critical-Care Nurses Transfer Guidelines Task Force. Guidelines for the transfer of critically ill patients. *Crit Care Med*. 1993;21(6):931-937.

Katona-Apte J, Mokdad A. Malnutrition of children in the Democratic People's Republic of North Korea. *J Nutr*. 1998;128(8):1315-1319.

Kikta MJ, Meyer JP, Bishara RA, Goodson SF, Schuler JJ, Flanigan P. Crush syndrome due to limb compression. *Arch Surg*. 1987;122(9):1078-1081.

Kuwagata Y, Oda J, Tanaka H, et al. Analysis of 2,702 traumatized patients in the 1995 Hanshin-Awaji earthquake. *J Trauma*. 1997;43(3):427-432.

Logue JN. The public health response to disasters in the 21st century: reflections on Hurricane Katrina. *J Environ Health*. 2006;69(2):9-13,26.

Matsuoka T, Yoshioka T, Tanaka H, et al. Long-term physical outcome of patients who suffered crush syndrome after the 1995 Hanshin-Awaji earthquake: prognostic indicators in retrospect. *J Trauma*. 2002;52(1):33-39.

Michaelson M, Taitelman U, Bursztein S. Management of crush syndrome. *Resuscitation*. 1984;12(2):141-146.

Noji EK. Public health issues in disasters. *Crit Care Med*. 2005;33(suppl 1):S29-S33.

Noji EK. The public health consequences of disasters. *Prehosp Disaster Med*. 2000;15(4):147-157.

Prezant DJ, Weiden M, Banauch GI, et al. Cough and bronchial responsiveness in firefighters at the World Trade Center site. *N Engl J Med*. 2002;347(11):806-815.

Safar P. Resuscitation potentials in mass disasters. *Prehosp Disaster Med*. 1986;2:34-47.

Schultz CH, Koenig KL, Noji EK. A medical disaster response to reduce immediate mortality after an earthquake. *N Engl J Med*. 1996;334(7):438-444.

Sever MS, Vanholder R, Lameire N. Management of crush-related injuries after disasters. *N Engl J Med*. 2006;354(10):1052-1063.

Shimazu T, Yoshioka T, Nakata Y, et al. Fluid resuscitation and systemic complications in crush syndrome: 14 Hanshin-Awaji earthquake patients. *J Trauma*. 1997;42(4):641-646.

Wisner B, Adams J. *Environmental Health in Emergencies and Disasters: A Practical Guide*. Geneva, Switzerland: WHO Press; 2003.

World Health Organization. Guidelines for the use of foreign field hospitals in the aftermath of sudden-impact disaster teams. *Prehosp Disaster Med.* 2003;18(4):278-290.

Web Sites

EM-DAT: Emergency Events Database. The OFDA/CRED International Disaster Database. http://www.em-dat.net.

Rapid Needs Assessment. Pan American Health Organization/World Health Organization http://www.paho.org/english/ped/te_rapa.htm.

UN International Strategy for Disaster Reduction. http://www.unisdr.org.