67 Natural Disaster Management

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Throughout history, natural disasters have exacted a heavy toll of death and suffering (Tables 67-1 and 67-2). During the past 25 years they have claimed more than 3 million lives worldwide, have adversely affected the lives of at least 800 million more people, and have resulted in property damage exceeding $50 billion.[73, 80, 103, 117] Recent natural catastrophes have included earthquakes in Los Angeles (1994)[67] and Kobe, Japan (1995),[88, 116, 148, 149] a series of devastating hurricanes in the Caribbean in 1998 (including hurricanes Mitch and Georges), severe flooding in the central United States in 1993 and California in 1998,[33,34,35, 39] tornadoes in Oklahoma and Texas (1999), global adverse weather conditions related to the El Niño phenomenon in 1997 and 1998, and the volcanic eruption of Mt. Soufriere on the island of Montserrat (1997).

Table 67-1. Mortality Estimates by Type of Disaster

DISASTER TYPE	DEATHS 1960-1969	1970-1979	1980-1989	1990-1999
Floods	28,700	46,800	38,598	103,870
Cyclones/hurricanes	107,500	343,600	14,482	201,790
Earthquakes	52,500	389,700	53,740	98,678
Other disasters			1,011,777	2,686
TOTAL			1,119,860	407,204

From Office of US Foreign Disaster Assistance: *Disaster history: significant data on major disasters worldwide, 1900-present,* Washington, DC, 1990, Agency for International Development; and Walker P, Walter J: *World disasters report: focus on public health,* Geneva, 2000, International Federation of Red Cross and Red Crescent Societies.

Table 67-2. Selected Natural Disasters of the Twentieth Century*

YEAR	EVENT	LOCATION	APPROXIMATE DEATH TOLL
1900	Hurricane	USA	6,000
1902	Volcanic eruption	Martinique	29,000
1902	Volcanic eruption	Guatemala	6,000
1906	Typhoon	Hong Kong	10,000

1906	Earthquake	Taiwan	6,000
1906	Earthquake/fire	USA	1,500
1908	Earthquake	Italy	75,000
1911	Volcanic eruption	Philippines	1,300
1915	Earthquake	Italy	30,000
1916	Landslide	Italy, Austria	10,000
1919	Volcanic eruption	Indonesia	5,200
1920	Earthquake/landslide	China	200,000
1923	Earthquake/fire	Japan	143,000
1928	Hurricane/flood	USA	2,000
1930	Volcanic eruption	Indonesia	1,400
1932	Earthquake	China	70,000
1933	Tsunami	Japan	3,000
1935	Earthquake	India	60,000
1938	Hurricane	USA	600
1939	Earthquake/tsunami	Chile	30,000
1945	Flood/landslide	Japan	1,200
1946	Tsunami	Japan	1,400
1948	Earthquake	USSR	100,000
1949	Flood	China	57,000
1949	Earthquake/landslide	USSR	20,000
1951	Volcanic eruption	Papua New Guinea	2,900
1953	Flood	North Sea coast	1,800
1954	Landslide	Austria	200
1954	Flood	China	40,000
1959	Typhoon	Japan	4,600
1960	Earthquake	Morocco	12,000
1961	Typhoon	Hong Kong	400
1962	Landslide	Peru	5,000
1962	Earthquake	Iran	12,000
1963	Tropical cyclone	Bangladesh	22,000
1963	Volcanic eruption	Indonesia	1,200
1963	Landslide	Italy	2,000
1965	Tropical cyclone	Bangladesh	17,000
1965	Tropical cyclone	Bangladesh	30,000

1965	Tropical cyclone	Bangladesh	10,000
1968	Earthquake	Iran	12,000
1970	Earthquake/landslide	Peru	70,000
1970	Tropical cyclone	Bangladesh	300,000
1971	Tropical cyclone	India	25,000
1972	Earthquake	Nicaragua	6,000
1976	Earthquake	China	250,000
1976	Earthquake	Guatemala	24,000
1976	Earthquake	Italy	900
1977	Tropical cyclone	India	20,000
1978	Earthquake	Iran	25,000
1980	Earthquake	Italy	1,300
1982	Volcanic eruption	Mexico	1,700
1985	Tropical cyclone	Bangladesh	10,000
1985	Earthquake	Mexico	10,000
1985	Volcanic eruption	Columbia	22,000
1988	Hurricane Gilbert	Caribbean	343
1988	Earthquake	Armenia SSR	25,000
1989	Hurricane Hugo	Caribbean	56
1990	Earthquake	Iran	40,000
1990	Earthquake	Philippines	2,000
1991	Tropical cyclone	Bangladesh	140,000
1991	Volcanic eruption	Philippines	800
1991	Typhoon/flood	Philippines	6,000
1991	Flood	China	1,500
1992	Hurricane Andrew	USA	52
1993	Earthquake	India	10,000
1995	Earthquake	Japan	6,000
1998	Hurricane Mitch	Central America	10,000

Data from Office of US Foreign Disaster Assistance: *Disaster history: significant data on major disasters worldwide, 1900-Present*, Washington, DC, 1999, Agency for International Development; and National Geographic Society: *Nature on the rampage, our violent earth,* Washington, DC, 1987, National Geographic Society.
*Disasters selected to represent global vulnerability to rapid-onset disasters.

The future appears to be even more frightening. Increasing population density in floodplains and in earthquake- and hurricane-prone areas points to the probability of future catastrophic natural disasters with millions of casualties.[75, 154, 163] Many natural disasters of large magnitude occur in remote areas, far from towns and hospitals. The roads frequently become impassable, bridges collapse, and inclement weather adds to the difficulties. The more remote the area, the longer it takes for external assistance to arrive, and the more the community will have to rely on its own resources, at least for the first several hours, if not days. Friends, neighbors, and relatives conduct the initial search and rescue of victims, provide basic first aid, and transport injured victims to the nearest health care facilities.

Good disaster management must link data collection and analysis to an immediate decision-making process.[15] The overall objective of disaster management from a public health perspective is to assess the needs of disaster-affected populations, match available resources to those needs, prevent further adverse health effects, implement disease control strategies for well-defined problems, evaluate the effectiveness of disaster relief programs, and improve contingency plans for various types of future disasters.[57]

The effects of disasters on the health of populations are quantifiable.[39] Common patterns of morbidity and mortality follow certain disasters.[162] Better epidemiologic knowledge of the causes of death and types of injuries and illnesses caused by natural disasters is essential to determine the relief supplies, equipment, and personnel needed to respond effectively.[2, 15, 72] In addition, results of disaster research provide informed advice about the probable health effects of future disasters, establish priorities for action by emergency medical services, and emphasize the need for accurate information as the basis for relief management decisions.[15, 63]

Proper planning and execution of disaster medical aid programs require knowledge of the types of disasters and resulting morbidity, mortality, and medical care needs. Emergency responders should be experts on how to handle the type of disaster most prevalent in their own communities because each type of disaster is characterized by different morbidity and mortality patterns and has different health care requirements.[15, 113] For example, hospitals along the Gulf Coast of the United States should plan for hurricanes, whereas those in California should plan for earthquakes.[43, 72, 85]

In addition, specific types of medical and health problems tend to occur at different times after a natural disaster's impact. With earthquakes, for example, the problem of severe injuries that require immediate trauma care must be handled mainly at the time and place of impact. The problem of increased risk of disease transmission can be handled later, however, because it takes longer to develop, and the greatest danger occurs with crowding and poor sanitation. Effective emergency medical response depends on anticipating the different medical and health problems and delivering the appropriate interventions when needed most.[140]

NATURE OF DISASTER

The World Health Organization (WHO) defines *disaster* as a sudden ecologic phenomenon of sufficient magnitude to require external assistance.[124, 165] At the community level, this can be defined operationally as any community emergency that seriously affects people's lives and property and that exceeds the community's capacity to respond effectively.[83]

The essence of a disaster is substantial environmental damage, which may be accompanied by large numbers of casualties. This chapter refers to limited incidents creating relatively small numbers of casualties and slight environmental disturbance as *multiple casualty incidents.* The term *disaster* is reserved for incidents that cause great disruption of the physical and social environments and that require extraordinary resources and special medical care, even in the absence of mass casualties.

True disasters affect a community in numerous ways. Roads, telephone lines, and other transportation and communication links are often destroyed. Public utilities and energy supplies may be disrupted. Substantial numbers of victims may be rendered homeless. Portions of the community's industrial or economic base may be destroyed or damaged. Casualties may require medical care, and damage to food sources and utilities may create public health threats.

PAST PROBLEMS IN NATURAL DISASTER MANAGEMENT

In ancient times, little mitigation was possible against the effects of disaster. Today, communications inform us rapidly of disasters and allow us to provide effective medical aid to victims. This requires adequate planning and brisk execution. Medical aid in many previous disasters has been well intentioned but poorly organized, with limited benefits.[57, 124]

Health decisions made during emergencies are often based on insufficient, nonexistent, or even false information, which results in inappropriate, insufficient, or unnecessary health aid, waste of health resources, or countereffective measures.[140] For example, large amounts of useless drugs and other consumable supplies are frequently sent to a disaster site. After the 1976 earthquake in Guatemala, 100 tons of unsorted medicines were airlifted to the country from foreign donors.[48, 50] Of these supplies, 90% were of no value because they consisted of medications that had expired, were already opened, or carried labels written in foreign languages. A similar situation occurred after the 1988 Armenian earthquake, when international relief operations sent at least 5000 tons of drugs and consumable medical supplies. Because of the difficulties with identification and sorting, only 30% of the drugs were immediately usable by the health workers in Armenia; 11% were useless, and 8% had expired. Ultimately, 20% of all the drugs provided by international aid had to be destroyed.[4] Other examples of inappropriate aid include sending mobile hospitals and teams of specialized trauma or emergency medicine specialists that arrive much too late and sending unprepared medical volunteers when nonmedical relief workers (e.g., sanitation engineers) would be more appropriate. The arrival of unprepared and inexperienced foreign personnel may damage the relief effort by tying up communication, transportation, and housing. These problems are all compounded in the vacuum created by the disaster, including the lack of communication, transportation, local supplies and support, and a decision-making structure. Because these relief operations are often conducted under the watchful eye of the media, medical relief efforts are often pejoratively called *the second disaster*.[89, 114]

INFORMATION MANAGEMENT SYSTEMS FOR DISASTER RESPONSE

Over the past several years, efforts have been made to develop rapid and valid disaster damage assessment techniques.[152, 166] These techniques must be able to define quickly the overall effects of the disaster impact, the nature and extent of the health problems, groups in the population at particular risk for adverse health events, specific health care needs of the survivors, local resources to cope with the event, and the extent and effectiveness of the response to the disaster by local authorities.[83, 145] Guha-Sapir and Lechat[71,72,73] have developed indicators for needs assessment in earthquakes (“quick and dirty” surveys), highlighting simplicity, speed of use, and operational feasibility. The techniques employed (e.g., systematic surveys, simple reporting systems) are methodologically straightforward. With suitable personnel and transport, estimates of relief needs can be quickly obtained.[32] Problems may arise, however, with the interpretation of data, particularly incomplete data, and in developing countries in which predisaster health and nutritional levels are unknown.

The ultimate goal of surveillance is to prevent or reduce the adverse health consequences of the disaster itself, as well as to optimize the decision-making process associated with management of the relief effort. These epidemiologic objectives can be simply defined as the *surveillance cycle:* the collection, analysis, and response to data.[57] The surveillance cycle must be repeated many times: immediately, with rapid assessments of problems using the most rudimentary data collection techniques; then short-term assessments involving the establishment of simple but reliable sources of data; and subsequently, ongoing surveillance to identify continuing problems and monitor response.

Field surveillance methods vary greatly by disaster setting and by the personnel and time available. Early field surveys must be simple and provide immediate answers that will directly prevent loss of life or injury. Subsequently, surveys can address issues such as the availability of medical care, assessment of the need for specific interventions, and epidemic control (a rumor clearinghouse), each of which demands more careful investigation. Surveillance must determine whether the effort is having a tangible impact on the population, or whether new strategies are needed.[147] Surveillance becomes an iterative, cycling process in which simple health outcomes are constantly monitored and interventions assessed for efficacy.

Finally, linking postdisaster information to a decision-making process is important.[72] In the rapid evolution of a disaster relief program, major decisions regarding relief are made early, hastily, and often irreversibly, so reliable early data to assist in making these decisions are vital. Organized data collection in disaster situations can greatly improve decision making. Adaptable questionnaires can assist in an efficient data collection operation.

Operational decisions depend on the phase of the disaster. In the early phase of relief, basic needs of water, food, clothing, shelter, and medical care must be met, after which the long-term process of rebuilding proceeds. Relief aid can often be squandered by overreacting to minor problems when excitement is great, needs are extensive, and scrutiny by the media is omnipresent.[140] Because everyone in the disaster area has needs and experiences loss, the challenge of early assessment is to decide where initial interventions will prevent the greatest loss of life or severe morbidity. The postimpact phase requires information on long-term rehabilitation and restoration of health services. Epidemiologic assessment, prioritization of needs, and ordering an appropriate response can have a major impact on the community's ability to return to normalcy in both the short and longer term.

HEALTH CARE NEEDS IN SPECIFIC NATURAL DISASTERS

Natural hazards that can cause substantial property damage, economic dislocation, and medical problems include earthquakes and associated phenomena, volcanic eruptions, and extreme weather incidents, such as heat waves and blizzards. Accounts of morbidity and mortality recorded after previous disasters can predict the medical care needs of future disaster victims and provide a foundation for disaster response planning.

Floods

Floods are the most common natural disasters. They affect more people worldwide and cause greater mortality than any other type of natural disaster.[73, 118, 163] They occur in almost every country, but 70% of all flood deaths occur in India and Bangladesh[103] (Figure 67-1). In the United States, floods cause more deaths than any other natural disaster, with most fatalities resulting from flash floods.[60]

Figure 67-1 During summer 1988, monsoon rains resulted in the most severe flooding ever recorded in Bangladesh. Water covered three fourths of the land area of Bangladesh, displacing up to 40 million persons from their homes. (*Courtesy Centers for Disease Control and Prevention and US Public Health Service.*)

Fast-flowing water carrying debris such as boulders and fallen trees accounts for the primary flood-related injuries and deaths. The main cause of death from floods is drowning, followed by various combinations of trauma, drowning, and hypothermia with or without submersion.[11] Persons submerged in cold water for up to about 40 minutes have been successfully resuscitated with 100% recovery of neurologic function.[118] Unfortunately, such resuscitations from clinical death require technologically advanced measures, which may not be available for days after a flood, even in a highly developed country such as the United States.

Among flood survivors, the proportion requiring emergency medical care is reported to vary between 0.2% and 2%.[139, 146] Most injuries requiring urgent medical attention are minor and include lacerations, skin rashes, and ulcers.[124] However, flood-associated lacerations are frequently contaminated, so primary wound closure should be done with caution. Primary closure without careful evaluation of the wound almost always requires reopening the wound and additional treatment within 24 to 48 hours.[11]

Increased incidence of snakebites was reported after floods in India and the Philippines.[158] In India, most snakebites were by cobras that had been driven by rising water to seek higher ground near towns and villages.

For some floods, substantial numbers of casualties caused by fire have been documented.[118] Fast-flowing water can break oil or gasoline storage tanks. If the film of oil is ignited, the fire may spread to buildings on land.

From a public health viewpoint, floods may disrupt water purification and sewage disposal systems, cause toxic waste sites to overflow, or dislodge chemical containers stored above ground.[51] In addition, makeshift evacuation centers with insufficient sanitary facilities may become substantially overcrowded.[125] The combination of these events may contribute to increased exposure to highly toxic biologic and chemical agents. Examples include the potential for waterborne disease transmission of such agents as enterotoxigenic *Escherichia coli, Shigella, Salmonella,* and hepatitis A virus.[139] The risk of transmission of malaria and yellow fever may be increased because of enhanced vector-breeding conditions.[124] In 1973 Ussher[158] reported that the most serious problems encountered after a flood in the Philippines were viral upper respiratory tract infections, which were probably caused by crowded conditions in temporary shelters.

Despite the potential for communicable diseases to follow floods, mass vaccination programs are counterproductive for a variety of reasons. They not only divert limited personnel and resources from other critical relief tasks, but also may create a false sense of security and cause persons who have been vaccinated to neglect basic hygiene.[49] Unfortunately, after floods the public often demands typhoid vaccine and tetanus toxoid, although no epidemic of typhoid after a flood has ever been documented in the United States.[95] In addition, antibodies to typhoid after immunization take several weeks to develop, and even then, vaccination protects only moderately. Likewise, mass tetanus vaccination programs are not indicated. Management of flood-associated wounds should include appropriate evaluation of the injured person's tetanus immunization history, and the person should be vaccinated only if indicated.

The proper approach to the problem of communicable diseases is to set up an epidemiologic surveillance system so that an increase in cases of communicable diseases in the flood-stricken area can be identified quickly. Particular attention should be given to diseases endemic to the area. For example, when floods occur in areas with endemic arthropod-borne encephalitides, arthropods known to transmit the disease should be monitored and areas should be sprayed if the vector population increases significantly after the flood.

Tropical Cyclones (Hurricanes or Typhoons)

Cyclones, hurricanes, and typhoons have killed hundreds of thousands and injured millions of people during the last 30 years (Figure 67-2).[75, 117] From 1900 to 1999 more than 14,000 people lost their lives in hurricanes in the United States (Table 67-3).[56] The greatest natural disaster in U.S. history occurred on Sept. 8, 1900, when a hurricane struck Galveston, Texas, and killed more than 6000 persons.[59, 103] In 1970 deaths resulting from a single tropical cyclone striking Bangladesh were estimated to exceed 250,000. As population growth continues along vulnerable coastal areas, deaths and injuries resulting from tropical cyclones will increase.[70, 141]

Figure 67-2 Satellite image of a hurricane and a cyclone striking Mexico simultaneously. (*Courtesy World Health Organization and Office of the UN Disaster Relief Coordinator.*)

Table 67-3. Hurricanes Causing More Than 100 Deaths in the United States, 1900-1982

STORM/AREA	YEAR	DEATHS
Texas (Galveston)	1900	6000
Florida (Lake Okeechobee)	1928	1836
South Texas, Florida (Keys)	1919	600-900*
New England	1938	600
Florida (Keys)	1935	408
Audrey/Louisiana, Texas	1957	390
Northeast United States	1944	390†
Louisiana (Grand Isle)	1909	350
Louisiana (New Orleans)	1915	275

Texas (Galveston)	1915	275
Camille/Mississippi, Louisiana	1969	256
Florida (Miami)	1926	243
Diane/Northeast US	1955	184
Florida (Southeast)	1906	164
Mississippi, Alabama, Florida (Pensacola)	1906	134
Agnes/Northeast US	1972	122

From French JG: Hurricanes. In Gregg MB, editor: *The public health consequences of disasters*, Atlanta, 1986, Centers for Disease Control.
*Includes more than 500 persons lost on ships at sea.
†Includes 344 persons lost on ships at sea.

Although hurricane winds do great damage, wind is not the primary killer in a hurricane. Hurricanes are classic examples of disasters that trigger secondary effects such as tornadoes and flooding that, together with storm surges, can cause extraordinarily high rates of morbidity and mortality. This was seen after the 1991 cyclone and sea surge in Bangladesh, in which 140,000 persons drowned, and during Hurricane Mitch in Central America in 1998, with thousands of drowning deaths.[66] Nine of 10 hurricane fatalities are drownings associated with storm surges.[58, 59, 123] The major rescue problem is locating persons stranded by rising waters and evacuating them to higher land. Other causes of deaths and injuries include burial beneath houses collapsed by wind or water, penetrating trauma from broken glass or wood, blunt trauma from floating objects or debris, or entrapment by mud slides that may accompany hurricane-associated floods.[31, 74] Many of the most severe injuries occur to persons who are in mobile homes during the storm, or those who are injured or electrocuted during postdisaster cleanup.[28, 29, 127]

Most persons who seek medical care after hurricanes do not require sophisticated surgical or intensive care services and can be treated as outpatients.[107, 132] The majority have lacerations caused by flying glass or other debris[74]; a few have closed fractures and other, mostly penetrating, injuries.[36, 42] Longmire et al[91, 92] studied injuries associated with hurricanes Frederic (1984) and Elena (1985). They found a statistically significant increase in lacerations, puncture wounds, chain saw injuries, burns, gasoline aspiration, gastrointestinal complaints, insect stings, and spouse abuse in the 2 weeks after the hurricane. The authors concluded that minor trauma treated in the outpatient setting created an urgent demand for primary care physicians and nurses skilled in managing minor surgical emergencies. In addition, although the number of chain saw injuries was small, the time-consuming nature of treating such wounds increased significantly the demands placed on remaining emergency department personnel to treat those with other injuries. As with flood-related wounds, emergency medical care providers should be aware that wounds may contain highly contaminated material such as soil or fecal matter.[122, 126] Because of this danger, primary wound closure should be done with caution.

Storm shelters are often severely crowded.[30] As with flood disasters, this crowding increases the probability of disease communication through aerosol or fecal-oral routes, particularly when sanitary facilities are insufficient.[16]

Trauma after a cyclone is not usually a major public health problem when compared with the need for water, food, clothing, sanitation, and other hygienic measures.[146] Studies demonstrate that sending fully equipped mobile hospitals and specialized surgical teams that arrive much too late at the disaster site is an ineffective response to a cyclone disaster. Nonmedical relief (e.g., epidemiologists, sanitation engineers, shelter, food, agricultural supplies) is probably more effective in reducing mortality and morbidity. On the other hand, field hospitals and emergency medical teams from outside the disaster-affected area may be useful in providing ongoing primary health care services to the community when all other health care facilities have been destroyed or severely damaged.[76] This was the case in St. Croix after hurricane Hugo[132] and in south Florida after hurricane Andrew.[157] These situations reemphasize the importance of conducting rapid assessments of public health needs before sending relief personnel and materials to a disaster.[125]

Tornadoes

Tornadoes are among the most violent of all natural atmospheric phenomena, as has been witnessed after recent devastating tornadoes in Oklahoma, Texas, and Alabama (Figure 67-3).[103] Although almost 700 tornadoes occur in the United States each year, only about 3% result in severe injuries requiring hospitalization.[90] Of 14,600 tornadoes studied between 1952 and 1973, only 497 caused fatalities, and 26 of these events accounted for almost half of the fatalities.[61] The Centers for Disease Control and Prevention (CDC) has reviewed the public health impact of tornadoes in great detail.[90]

Figure 67-3 Tornado striking McConnell Air Force Base, Kansas, April 26, 1991. (*Courtesy US Air Force.*)

The destruction caused by tornadoes results from the combined action of strong rotary winds and the partial vacuum in the center of the vortex.[102] For example, when a tornado passes over a building, the winds twist and rip at the outside. Simultaneously, the abrupt pressure reduction in the tornado's eye causes explosive pressures inside the building. Walls collapse or topple outward, windows explode, and the debris from this destruction can be driven as high-velocity missiles through the air. Buildings made of unreinforced masonry, wood frame buildings, and those with large window areas will likely have the most extensive damage.[87] Building practices may be largely responsible for the severity of injury resulting from tornadoes.[20]

In the last 50 years, tornadoes have been responsible for more than 9000 deaths in the United States.[65] About 4% of all injuries sustained were fatal. For every person seriously injured or killed, approximately 44 others required some emergency medical attention.[68]

Victims of tornado disasters show characteristic patterns of fatal and nonfatal injuries. The leading cause of death is craniocerebral trauma,[18, 96] followed by crushing wounds of the chest and trunk.[6, 139] Fractures are the most frequent nonfatal injury. Lacerations, penetrating trauma with retained foreign bodies, and other soft tissue injuries also frequently occur. A high percentage of wounds among tornado casualties are heavily contaminated.[19, 77] In many instances, foreign materials such as glass, wood splinters, tar, dirt, grass, and manure are deeply embedded in areas of soft tissue injury.[96] Wound contamination appears to be a major factor contributing to the high rate of postoperative sepsis for tornado victims who require surgery, even under conditions in which patients receive highly skilled and prompt surgical debridement. Sepsis is common in both minor and major injuries; sepsis affects one half to two thirds of patients with minor wounds.[6] In 1956 Hight et al[77] examined the postoperative course of patients after the Worcester tornado and found sepsis in 12.5% to 23.0% of orthopedic and neurosurgical patients with lacerations, three cases of gas gangrene, but no cases of tetanus.

Three studies have looked specifically at the species of bacteria that contaminate wounds sustained during tornadoes.[19, 62, 81] These revealed frequent infection with aerobic gram-negative bacilli, presumably derived from soil.

Volcanic Eruptions

Volcanic eruptions have claimed more than 266,000 lives in the past 400 years, with fatalities occurring in about 5% of eruptions.[17, 144] Some of the more catastrophic eruptions in history include the eruption of Krakatoa (Indonesia), which caused 36,000 deaths; of Mt. Pelee in 1902, which caused the destruction of St. Pierre in Martinique and the deaths of 28,000 persons; of Nevado del Ruiz in Colombia, which claimed 25,000 lives; and of Mt. Pinatubo in the Philippines, with effects still ongoing because of persistent mudflows. The U.S. Geological Survey has identified about 35 volcanoes in the western United States and Alaska that are likely to erupt in the future. Most of these are in remote rural areas and are not likely to result in disaster. A few, such as Mt. Hood, Mt. Shasta, Mt. Rainier, and the volcano underlying Mammoth Lakes in California, are near population centers.[5, 12] Because of the increasing population density in areas of volcanic activity, volcanic hazards are of growing concern.[44, 75, 86, 103]

Eruptions have immediate life-threatening health effects through suffocation from inhalation of massive quantities of airborne ash, scalding from blasts of superheated steam, and surges of lethal gas (Table 67-4).[10, 13] Pyroclastic flows and surges are particularly lethal.[8] These are currents of extremely hot gases and particles that flow down the slopes of a volcano at tens to hundreds of meters per second and cover hundreds of square kilometers. Because of their suddenness and speed, pyroclastic flows and surges are difficult to escape.

Table 67-4. Principal Health Effects Caused by Volcanic Eruptions

ERUPTIVE EVENT	CONSEQUENCE	HEALTH EF
Explosions	Lateral blast, rock fragments Air shock waves	Trauma, skin burns Lacerations from brok
Hot ash release	Glowing avalanches Ashflows and ashfalls Lightning Forest fires	Skin and lung burns Asphyxiation Electrocution Burns
Melting ice, snow, and rain accompanying eruption	Mudflows, floods	Engulfing, drowning
Lava	Forest fires	Burns
Gas emissions: sulfur dioxide, carbon monoxide, carbon dioxide, hydrogen sulfide, hydrogen fluoride	Pooling in low-lying areas and inhalation	Asphyxiation, airway
Radon	Radiation exposure	Lung cancer
Earthquakes	Building damage	Trauma

From Baxter PJ, Bernstein RS, Buist AS: *Am J Public Health* 76(suppl):84, 1986.

Mudflows, or lahars, account for at least 10% of volcano-related deaths.[161] These are flowing masses of volcanic debris mixed with water. The mud is sometimes scalding hot, and entrapped persons may sustain severe burns. A relatively minor eruption of snow-capped Nevado del Ruiz in 1985 triggered lahars from the volcano's icecap that buried more than 22,000 persons in Colombia, South America.[144]

An indirect effect of volcanic activity is accumulation of toxic volcanic gases in deep crater lakes.[119, 143] Sudden release of these gases can be catastrophic; carbon dioxide released from Lake Monoun and Lake Nyos in Cameroon in 1984 and 1986, respectively, claimed 1800 lives. Other toxic effects of these gas releases include pulmonary edema, irritant conjunctivitis, joint pain, muscle weakness, and cutaneous bullae. In the rare event of a ground-level release of toxic gases or aerosols (e.g., from a vent opening to the atmosphere from the side of the volcano), equipment for monitoring atmospheric concentrations of sulfur dioxide, hydrogen sulfide, hydrofluoric acid, carbon dioxide, and other gases should be available.[10, 13]

A volcanic eruption may also generate tremendous quantities of ashfall.[101, 133] Buildings have been reported to collapse from the weight of ash accumulating on roofs, resulting in severe trauma to the occupants.[97] Ash can also be irritating to eyes (causing corneal abrasions), mucous membranes, and the respiratory system.[94] Upper airway irritation, cough, and bronchospasm, as well as exacerbation of chronic lung disease, are common findings in symptomatic patients.[8] In extremely high concentrations, as in the path of a pyroclastic flow or near the volcanic vent during an ashfall, volcanic ash may cause severe tracheal injury, pulmonary edema, and bronchial obstruction, leading to death from acute pulmonary injury or suffocation.[97] After the eruption of Mt. St. Helens in 1980, 23 immediate deaths were reported (Figure 67-4). Postmortem examinations revealed that 18 of these resulted from asphyxia.[54] In most asphyxiated victims, the ash mixed with mucus and formed plugs, obstructing the trachea and main bronchi. Finally, delayed onset of ash-induced mucus hypersecretion or obstructive airway disease may occur.[9]

Figure 67-4 Eruption of Mt. St. Helens, Washington State, May 18, 1980. (*Courtesy of the US Geological Survey*.)

Victims who recover from volcano-generated mudflows may have severe dehydration, burns, and eye infections.[55] Reports of surgical care after the volcanic eruption in Colombia in 1985 showed that primary closure of wounds contaminated by mud and other volcanic material resulted in major complications.[120] These complications included gangrene necessitating amputation, osteomyelitis, compartment syndrome, and sepsis.

Most volcanic deaths are caused by immediate suffocation and, to a lesser extent, by burns or blunt trauma. Advanced cardiac and trauma life support capabilities, even if immediately available, would probably arrive too late to save asphyxiated victims. Persons who may develop severe respiratory distress syndrome should be admitted to an intensive care unit (ICU) for appropriate respiratory supportive measures, ranging from continuous positive airway pressure to mechanical ventilation with positive end-expiratory pressure.[97] Hospitals in the vicinity of both active and dormant volcanoes should be prepared to deal with a sudden influx of victims with severe burns and lung damage from inhalation of hot ash, as well as multiple varieties of trauma.[8, 13]

Earthquakes

An earthquake of great magnitude is one of the most destructive events in nature. During the past 20 years, earthquakes have caused more than a million deaths and injuries worldwide.[117] In the United States, approximately 1600 deaths attributed to earthquakes have been recorded since colonial times, of which more than 1000 have occurred in California (Figure 67-5).[109, 142] Hospitals and other health care facilities are particularly vulnerable to the damaging effects of an earthquake. Because of loss of power and water supply, equipment (e.g., x-ray and kidney dialysis machines, ventilators, blood analyzers) and hospital facilities (e.g., ICUs and surgical theaters) cannot function normally when they are most needed.[3, 112, 130]

Figure 67-5 Earthquake risk in the continental United States. Triangles represent active seismic areas from January 1937 to May 1997.

Disaster medical planners should note injury type and/or diagnostic classification among survivors to determine the medical care needed. The primary cause of death and injury from earthquakes is the collapse of buildings that are not adequately designed for earthquake resistance, are built with inadequate materials, or are poorly constructed (Figure 67-6).[64, 93] Factors determining the number of people killed when a building collapses include how badly trapped they are, how severely they are injured, how long they must wait for rescue, and how long they can survive without medical attention.[40, 41, 115]

Figure 67-6 Main street in devastated Armenian village showing complete collapse of all buildings after Dec. 7, 1988, earthquake. (*Courtesy Eric K. Noji.*)

Deaths resulting from major earthquakes can be instantaneous, rapid, or delayed.[88, 149] Instantaneous death can be caused by severe crushing injuries to the head or chest, external or internal hemorrhage, or drowning from earthquake-induced tidal waves (tsunamis). Rapid death occurs within minutes or hours and can be caused by asphyxia from dust inhalation or chest compression, hypovolemic shock, or exposure (e.g., hypothermia). Delayed death occurs within days and can be caused by dehydration, hypothermia, hyperthermia, crush syndrome, or postoperative sepsis.[137]

As with most natural disasters, the majority of those requiring medical assistance have minor injuries such as superficial lacerations, sprains, and bruises.[128] The next most frequent reason for seeking medical attention is simple fractures not requiring operative intervention.[139] For example, after the 1968 earthquake south of Khorasan, Iran, only 368 (3.3%) of 11,254 persons injured required inpatient care. Hospitalized patients included those with serious multiple fractures or internal injuries, hypothermia, sepsis from wound infections, or multiple organ failure requiring surgery or other intensive care services.[99]

More detailed inpatient information is available from data collected on 4832 patients admitted to hospitals after the 1988 earthquake in Armenia.[115] Consistent with findings from other major earthquakes, combination injuries constituted 39.7% of the cases. Superficial trauma, such as lacerations and contusions, was the most frequently observed injury (24.9%), followed by head injuries (22%), lower extremity injuries (19%), crush syndrome (11%), and upper extremity trauma (10%).

Infected wounds and gangrene were major problems after the Armenian earthquake.[111] Persons who have been trapped by rubble for several hours or days may also develop compartment syndromes requiring fasciotomy or amputation. These persons may have significant rhabdomyolysis and must be watched closely for signs and symptoms of crush syndrome such as hypovolemic shock, hyperkalemia, renal failure, or fatal cardiac arrhythmias.[14, 104, 106] After the 1988 earthquake in Armenia, more than 1000 victims trapped in collapsed buildings developed crush syndrome as a result of limb compression; 323 developed secondary acute renal failure requiring renal dialysis.[106]

Heavy dust is produced by crumbling buildings immediately after earthquakes. For trapped victims, this dust is a life-threatening hazard that may cause asphyxiation or upper airway obstruction.[78] Fulminant pulmonary edema from dust inhalation may also be a delayed cause of death.[137] Asbestos and other particulate matter in the dust are both subacute and chronic respiratory hazards for trapped victims, as well as for rescue and cleanup personnel. The degree of hazard depends on the characteristics and toxicity of the dust.[109]

Burns and smoke inhalation from fires used to be major hazards after an earthquake. For example, after the 1923 earthquake in Tokyo, more than 140,000 persons perished, principally because of fires that broke out in a city in which most buildings were constructed from highly flammable paper (shoji) and wood material. Since 1950, however, the incidence of burns has decreased considerably.[41]

To maximize saving trapped victims and increase their chances of survival, search and rescue teams must respond rapidly after a building collapses.[105] Studies of the 1980 Campania-Irpinia, Italy earthquake[46, 47] and the 1976 Tangshan, China earthquake[167] show that the proportion of trapped people found alive declined as delay in extrication increased. In the Italian study, a survey of 3619 survivors showed that 93% of persons who were trapped and survived were extricated within the first 24 hours and that 95% of the deaths recorded occurred while the victims were still trapped in rubble.[47] Estimates of the survivability of victims buried under collapsed earthen buildings in Turkey and China indicate that within 2 to 6 hours, less than 50% of those buried are still alive.

Although it cannot be determined whether a trapped person dies immediately or survives for some time under the debris, more people would be saved if they were extricated sooner. Safar,[136] studying the 1980 earthquake in Italy, concluded that 25% to 50% of victims who were injured and died slowly could have been saved if lifesaving first aid had been rendered immediately. As suggested by these data, if any significant reduction in earthquake mortality is to be achieved, appropriate search and rescue action must be provided within the first 2 days after the impact.

Paralleling the speed required for effective search and extrication is the speed with which emergency medical services must be provided.[138] The greatest demand occurs within the first 24 hours.[150] In fact, injured people usually seek medical attention at emergency departments only during the first 3 to 5 days, after which time hospital case-mix patterns return almost to normal.[148] The critical importance of early emergency care was seen in the number of admissions to a field hospital after the 1976 earthquake in Guatemala.[48, 50] From day 6 on, admissions fell dramatically despite intensive efforts to find injured people in remote rural areas of the impact zone, indicating that specialized field hospitals that arrived a week or more after an earthquake are generally too late to help during the emergency phase. After the Armenian earthquake, only 22 (2.4%) of the 902 patients requiring hospitalization at a large hospital were admitted 7 or more days after the impact.[115]

With most earthquakes, trauma caused by the collapse of buildings is the cause of most deaths and injuries. However, a surprisingly large number of victims require acute care for nonsurgical problems, such as acute myocardial infarction, exacerbation of chronic diseases (e.g., diabetes, hypertension), anxiety and other mental health problems, respiratory disease from exposure to dust and asbestos fibers from rubble, and near drowning because of flooding from broken dams. An example of the adverse effects of an earthquake on medical conditions was observed after a magnitude 6.7 earthquake in Athens, Greece. A 50% increase in deaths from myocardial infarction was documented during the first 3 days after the earthquake, peaking on the third day.[84, 153] Finally, an earthquake may precipitate a major technologic disaster by damaging or destroying nuclear power stations, hospitals with dangerous biologic products, hydrocarbon storage areas, and hazardous chemical plants.

As with most natural disasters, the risk of secondary epidemics is minimal, and only mass vaccination campaigns based on results of epidemiologic surveillance are appropriate after earthquakes.[151]

PRACTICAL ISSUES IN NATURAL DISASTER RESPONSE

Mass Casualty Care

A disaster may create casualties in excess of the capacity of the local health care system. The approach to patient evaluation and treatment is quite different under disaster situations resulting in large numbers of casualties.[23, 24, 53] Although some principles of medical care are unchanged in a mass casualty incident, others must be altered to achieve the best overall result.[131] The health care system must adapt to this situation with four measures: simplifying care (austerity); rationing care (adopting a triage ethic); calling for outside help; and in circumstances of catastrophe, instituting mass care measures typical of battlefield medicine. Many compromises in work methods eliminate attention to details that would be required in less urgent situations. Physicians and nurses often perform procedures beyond the scope of their usual practices. Professional functions and roles are widely shared among physicians, nurses, and paramedics. These adaptations allow available resources to serve more victims.[160]

Austerity

To be effective, disaster medical care must be confined to basic measures that preserve life and function. Examinations, techniques, appliances, and drugs that are not essential to patient survival or preservation of function are luxuries. It may be necessary to perform fracture reductions and other minor surgical procedures with oral narcotic analgesia only. Orthopedic devices are often improvised. Outdated drugs are better than no drugs. The level of austerity is determined by the health care personnel, supplies, and equipment available at the disaster treatment site.

Triage And Rationing

Initial management of mass casualties includes triage, basic field stabilization, and transportation. In general, *triage* can be defined as the prioritization of patient care based on severity of injury or illness, prognosis, and availability of resources.[134, 135] The goal of triage is to select those patients in greatest need of immediate medical attention and to arrange for that treatment. It is a concept born on the world's battlefields, by which victims are classified and treated based on the seriousness of their injuries. Military surgeons recognized that the number of victims produced in battle could overwhelm medical resources. Some persons suffer injuries that would be fatal even under ideal circumstances in which resources are unlimited. Attempts at salvaging mortally wounded individuals with heroic measures under conditions of limited personnel and supplies may deprive other victims of care for life-threatening but correctable conditions. The "walking wounded" sustain injuries that are survivable even if the provision of definitive medical care is significantly delayed. Thus, in the humanitarian interest of providing the greatest good for the greatest number of persons, methods of classification have been developed that facilitate treatment prioritization. The first victims treated are those with life-threatening injuries that can be readily stabilized without the expenditure of massive amounts of limited resources. The next priority is persons who have sustained injuries likely to cause significant morbidity, which would be appreciably lessened by early intervention. Catastrophically injured patients (e.g., those with burns involving 95% body surface area) who have a minimal chance for survival despite optimal medical care are provided comfort measures and may need to be left to die (Box 67-1). Spending time on patients who are not likely to live leaves other patients who might be saved awaiting care. If too much time intervenes, these patients also may become nonsalvageable. In addition to the nature and urgency of the patient's systemic condition, triage decisions must be sensitive to factors affecting prognosis, such as age, general health, physical condition of the patient, the qualifications of the responders, and availability of key supplies and equipment.[131]

Box 67-1 TRIAGE CATEGORIES BY INJURY TYPE

SIMPLE TRIAGE

Immediate (Priority I)

Asphyxia
Respiratory obstruction from mechanical causes
Sucking chest wounds
Tension pneumothorax
Maxillofacial wounds in which asphyxia exists or is likely to develop

Shock caused by major external hemorrhage
Major internal hemorrhage
Visceral injuries or evisceration
Cardiopericardial injuries
Massive muscle damage
Severe burns over more than 25% of body surface area
Dislocations
Major fractures
Major medical problems readily correctable
Closed cerebral injuries with increasing loss of consciousness

Delayed (Priority II)

Vascular injuries requiring repair
Wounds of the genitourinary tract
Thoracic wounds without asphyxia
Severe burns over less than 25% of body surface area
Spinal cord injuries requiring decompression
Suspected spinal cord injuries without neurologic signs
Lesser fractures
Eye injuries
Maxillofacial injuries without asphyxia
Minor medical problems
Victims with little chance of survival under the best conditions

MASS CASUALTY TRIAGE WITH AN OVERWHELMING NUMBER OF INJURIES

Immediate (Priority I)

Asphyxia
Respiratory obstruction from mechanical causes
Sucking chest wounds
Tension pneumothorax
Maxillofacial wounds in which asphyxia exists or is likely to develop
Shock caused by major external hemorrhage
Dislocations
Severe burns over less than 25% of body surface area*
Lesser fractures*
Major medical problems that are readily treatable

Delayed (Priority II)

Major fractures (if able to stabilize)*
Visceral injuries or evisceration*
Cardiopericardial injuries*
Massive muscle damage*
Severe burns over more than 25% of body surface area*
Vascular injuries requiring repair
Wounds of the genitourinary tract
Thoracic wounds without asphyxia
Closed cerebral injuries with increasing loss of consciousness*
Spinal cord injuries requiring decompression*
Suspected spinal cord injuries without neurologic signs
Eye injuries
Maxillofacial injuries without asphyxia
Complicated major medical problems*
Minor medical problems
Victims with little chance of survival under the best conditions

Data from Office of Emergency Services, State of California.
*Conditions that have changed categories.

Triage procedures are routinely used in civilian multiple or mass casualty incidents and are essential in disaster incidents. Prioritization of victims may be needed with smaller numbers of casualties when environmental conditions, remote settings, or unusual circumstances limit availability of medical care or ease of evacuation. The decision to evacuate persons with a reasonable chance of survival before mortally injured victims may be necessary in mountain and cave rescues, or with overland transport from isolated wilderness regions. Effective triage is critical to the success of any disaster care operation and should be performed by a senior and knowledgeable provider. The essential differentiation is “now” versus “not now.” In disaster triage the moribund victim unlikely to survive is classified as “not now,” when in ordinary circumstances he or she would be “immediate.”

Triage methods can be qualitative and quantitative.[82, 98, 155] *Qualitative methods* classify patients into subjective categories (e.g., immediate, delayed, minor, expectant). Two-tier, three-tier, four-tier, and five-tier systems have been described (Box 67-2). Any qualitative triage method can be used successfully in a disaster. Each ranks patients relative to others and to the available care, and each requires periodic reconsideration for treatment.

Box 67-2 TRIAGE RATING SYSTEM

FIVE-TIER SYSTEM (USED IN MILITARY TRIAGE)

Dead or will die
Life threatening—readily correctable
Urgent—must be treated within 1 to 2 hours
Delayed—noncritical or ambulatory
No injury—no treatment necessary

FOUR-TIER SYSTEM

Immediate—seriously injured, reasonable chance of survival
Delayed—can wait for care after simple first aid
Expectant—extremely critical, moribund
Minimal—no impairment of function, can either treat self or be treated by a nonprofessional

THREE-TIER SYSTEM

Life threatening—readily correctable
Urgent—must be treated within 1 to 2 hours
Delayed—no injury, noncritical, or ambulatory

TWO-TIER SYSTEM

Immediate—life-threatening injuries that are readily correctable on scene, and those that are urgent
Delayed—no injury, noncritical injuries, ambulatory victims, moribund, and dead

Quantitative methods assign an objective score to each patient based on initial clinical status. Various systems based on anatomic indicators of injury severity, physiologic measurements, and mechanisms of injury have been developed to predict outcomes, including the Trauma Score.[37, 38] Many emergency medical systems use the revised Trauma Score for field triage and as a guide for patient routing in tiered trauma treatment systems.[37] Although experienced physicians frequently rely on their best medical judgment to triage patients, medically inexperienced personnel may benefit from such an algorithmic approach to assessment and triage. Suppose that several members of an isolated mountain village were injured during an earthquake, that the village had only one health care worker, and that evacuation and treatment resources were limited. Decisions would have to be made regarding who would be evacuated first and who would be treated first. A trauma assessment based on physiologic variables could provide a relatively objective evaluation of the victim's condition and a rational basis for the allocation of scarce resources. The use of such standardized scoring systems for triage decisions, however, remains to be studied in the disaster setting. Triage methods founded on scoring systems require familiarity with the scoring systems. They cannot be used by disaster medical personnel unfamiliar with their application or modification.

Mechanics of the Triage Process

Triage should begin as soon as trained medical personnel arrive on the scene. A rapid survey is performed, noting the number of victims, hazards to victims and rescuers, and the need for additional help. This information should be relayed rapidly to the communication centers responsible for the dispatch of emergency services so additional help can be mobilized as early as possible. The most qualified medical person present should be designated the provisional triage officer. The triage officer should not be assigned other duties and should not become extensively involved in patient care. During the initial survey, each victim is rapidly assessed for immediately correctable life-threatening problems, such as airway obstruction, vigorous hemorrhage, or nonfatal penetrating chest injuries. Initial care should be limited to correction of these problems; resuscitation and definitive care have no role at this stage. Care should be limited to manually opening airways and controlling external hemorrhage.[136] Physical hazards may influence the decision to provide further care on site or delay additional therapy until victims are transported a safe distance to a casualty collection point. As additional experienced emergency medical personnel arrive, the role of triage officer should be assumed by the most experienced and knowledgeable person present. Advanced medical knowledge is an asset in minimizing triage errors. However, field-experienced physicians are relatively rare. Successful disaster triage under mock conditions can be performed by appropriately trained advanced emergency medical technicians or by experienced nurses. Triage is a dynamic process. Continued clinical deterioration or improvement may change the initial decision to evacuate or treat a victim. Triage should be performed whenever the responsibility for a victim’s care is transferred.[159]

Adjuncts to Triage

A triage tag is a paper tag intended to show the triage category in which a patient has been classified. Most bear color codes designating triage category. All enforce the use of the particular scheme of categorization for which they were designed, such as “immediate,” “delayed,” “minor,” and “expectant,” depending on injury severity and prognosis. Most are deliberately simple, such as the METTAG (Figure 67-7, *A*), and bear only minimal information to identify the patient and indicate triage class and site of injury. Others carry more information and serve as an abbreviated medical record (Figure 67-7, *B*). Vayer et al[159] reported that the tags had been used effectively in only a few multicasualty incidents. These authors recommend that triage tags be abandoned and replaced by a system of “geographic triage” that sorts casualties into areas reserved for patients of similar priority for treatment. Simultaneously, some disaster medical systems are recasting their “triage tags” as “victim tracking tags” in an elaborate evacuation system.

A. **B.**

Figure 67-7 Examples of disaster tag and chart. **A,** METTAG. **B,** Multiple casualty incident chart. (**A,** *Courtesy Journal of Civil Defense, Starke, Fla.* **B,** *Courtesy Stanford Hospital, Stanford, Calif.*)

On-Site Medical Care

The amount and type of care administered at disaster sites depend on several factors.[121] If the number of patients is small and sufficient prehospital personnel and transportation resources are available, on-site medical care can proceed normally, with rapid stabilization and transportation to nearby hospitals. When extrication is prolonged, potentially lifesaving interventions, such as intravenous fluids for hypovolemic shock, should be instituted.[136] On the other hand, early rapid transportation with minimal treatment should be practiced in circumstances such as danger to rescuers and casualties from fire, explosion, falling buildings, hazardous materials, and extreme weather conditions.[45]

With an overwhelming number of casualties that exceed transportation capacities, advanced field medical treatment may be beneficial because hours may pass before seriously injured patients can be evacuated.[7] This may necessitate the establishment of field hospitals with operating theater capabilities.[100] Such a field hospital may be set up in a large building such as a school or church. Casualties are brought to the field hospital from the disaster site for further assessment and initial treatment of injuries. After observation and stabilization, they are either sent home or transported to a hospital.

Evacuation of slightly injured and ambulatory persons may rapidly overwhelm local hospitals before the arrival of more severely injured victims.[129] Under these conditions, local treatment may be preferable to evacuation of the severely injured victims.

Communication From Disaster Site to Hospital

Local emergency communications or the disaster operations center should alert hospitals in the affected area of a possible mass or multiple casualty situation. This report should include number of injured and, specifically, number of seriously injured and number for whom ambulatory treatment is sufficient.[22] Hospitals should report the following information to the local emergency communications center:

1. Bed availability
2. Number of casualties received thus far
3. Number of additional casualties that the hospital is prepared to accept
4. Specific items in short supply

Specific Clinical Issues

Wound infections may occur in virtually all types of disasters. Infected wounds and gangrene were major problems after the Armenian earthquake.[111] In hurricanes or tornadoes, persons may be cut by flying glass and other potentially highly contaminated material.[124, 165] Because of this, all wounds should be copiously flushed with saline. Primary closure of heavily contaminated wounds may result in major complications, as occurred after the Armero volcanic eruption in Colombia. If lacerations are old (more than 6 to 12 hours) or appear contaminated, they should be treated by debridement and left open for primary delayed closure for a 3-day period.[21] This allows an opportunity to observe the wound for the development of infection. For tetanus prophylaxis, all patients should receive a tetanus booster, and if the wound is highly contaminated, tetanus immune globulin (Hypertet) should be administered.

Victims with blunt trauma, such as those trapped by rubble for several hours or days, should be watched closely for signs and symptoms of crush syndrome, such as cardiac arrhythmias and renal failure. [116] Fulminant pulmonary edema from dust inhalation may also be a delayed cause of mortality for victims of building collapse. [111]

PUBLIC HEALTH PROBLEMS

Epidemics

Natural disasters are often followed by rampant rumors of epidemics, such as typhoid, cholera, or rabies, or unusual conditions, such as increased snakebites and dog bites. Such unsubstantiated reports gain great public credibility when printed as facts in newspapers or reported on television or radio. After disasters in developing countries, any disruption of the water supply or sewage treatment facilities is usually accompanied by rumors of outbreaks of cholera or typhoid. Such rumors may well reflect psychologic fears and anxieties about a disastrous event rather than an imminent problem. Although natural disasters do not usually result in outbreaks of infectious disease, they may increase disease transmission.[1, 140] In addition, information on disease incidence in most developing countries is poor, and some outbreaks may have been missed by public health authorities.[13, 49] The most frequently observed increases in communicable disease are caused by fecal contamination of water and by respiratory spread, such as measles in refugee camps.[26, 27]

During the past 60 years, outbreaks of communicable disease after natural disasters have been unusual. Disasters can contribute to transmission of disease, however, and persons responsible for managing disaster relief operations should establish a surveillance system and institute appropriate sanitary and medical measures to prevent outbreaks.[15, 63, 69, 140, 164] Mass vaccination programs are rarely necessary.[25] A clearinghouse for rumors is helpful not only in developing countries, but also in disasters occurring in urban settings of industrialized countries.

Disposition of Dead Bodies

The public and government authorities are usually greatly concerned about the danger of disease transmission from decaying corpses (Figure 67-8). Responsible health authorities should recognize, however, that the health hazards associated with unburied bodies are minimal, particularly if death resulted from trauma.[79] Such bodies are unlikely to cause outbreaks of diseases such as typhoid, cholera, or plague, although they may transmit agents of gastroenteritis or food poisoning to survivors if the bodies contaminate streams, wells, or other water sources.[124] Despite the negligible health risk, dead bodies represent a delicate social problem. Demands for mass burial or cremation are certainly not justified on public health grounds, and mass cremations require tremendous quantities of fuel.

A. **B.**

Figure 67-8 **A,** Coffins lining the street in the city of Leninakan after the 1988 earthquake in Armenia. (*Eric K. Noji photo*.) **B,** Three horses were killed as a result of falling debris during the 1906 San Francisco earthquake. (**A,** *Courtesy Eric K. Noji*. **B,** *Courtesy Eric Swenson, US Geological Survey*.)

Health Effects

Table 67-5 outlines short-term health effects from natural disasters that require effective emergency medical care with an appropriate public health response. The overall objective of disaster management is to assess the needs of disaster-affected populations, to match resources to needs efficiently, to prevent further adverse health effects, to evaluate relief program effectiveness, and to plan for future disasters.[108]

Table 67-5. Short-Term Effects of Major Natural Disasters

EFFECTS	EARTHQUAKES	HIGH WINDS (WITHOUT FLOODING)	TSUNAMIS	FLOO FI
Deaths	Many	Few	Many	Few
Severe injuries requiring extensive care	Overwhelming	Moderate	Few	Few
Increased risk of communicable diseases	Potential (but small) risk after all major disasters (probability rises as ov increases and sanitation deteriorates)			
Food scarcity (may occur because of factors other than food shortage)	Rare	Rare	Common	Common
Major population movements may occur in heavily damaged urban areas)	Rare	Rare	Common	Common

Modified from *Emergency health management after natural disaster,* Office of Emergency Preparedness and Disaster Relief Coor
Scientific Publication No 407, Washington, DC, 1981, Pan American Health Organization.

All natural disasters are unique in that each affected region of the world has different social, economic, and health backgrounds. Recognition of similarities among the health effects of different natural disasters, however, can ensure that health and emergency medical relief and limited resources are well managed.[72]

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