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**Abstract:**

This article is part of a collaborative effort by experts in the field of emergency preparedness to complete an overview begun by the late Michael Shannon, MD, MPH, on the current challenges and future directions in pediatric disaster readiness. This particular article, "Preparing for Natural Disasters," will address pertinent clinical and disaster management issues relating to caring for children and families impacted by natural disasters.

# Preparing for Natural Disasters

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A “disaster” denotes a low-probability but high-impact event that causes a large number of individuals to become ill or injured. The International Federation of Red Cross and Red Crescent Societies defines a disaster as an event that causes more than 10 deaths, affects more than 100 people, or leads to an appeal for assistance by those affected.<sup>1</sup> A “natural disaster” is one in which a large number of individuals become ill or injured secondary to events that are not directly caused by humankind. These types of disasters range from meteorological events such as hurricanes and tsunamis to infectious disease epidemics of influenza or outbreaks of foodborne illness. The response to these events will be varied, but all have the same downstream impact of overburdening the health care system, potentially impacting care. Challenges persist to prepare for these events especially the physical and psychologic effects on children.

## METEOROLOGIC EVENTS

Large-scale natural disasters, such as hurricanes and earthquakes, will often require cooperation of multiple agencies and services at the local, state, and federal level. These systems may work together, in parallel, or most often in a mixed model that evolves over time as both the consequences and medical needs of the disaster become evident and as the agencies themselves have the opportunity to entrench and organize. Within the context of preparing to meet the needs of an unknown number of patients with an as yet unclear severity of trauma and illness, it is essential to recognize that pediatric patients may encompass a significant percentage of the patients seen and that personnel trained in pediatric care should be fully integrated into the disaster management and emergency care system.

Preparation for large-scale natural disasters must include consideration of a broad range of needs. These include injuries or problems directly attributable to the disaster, such as injuries resulting from a lack of services (electricity, heat, shelter, or

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access to adequate food and water). In addition, patients with preexisting medical conditions add to the stress and burden of a system that has been overloaded and may be structurally damaged. There will be a growing population of displaced persons who lack adequate housing, have limited access to food and water, have decreased mobility due to loss of private and public transportation, will lack communication capability, and will potentially be separated from their family. All of these problems are multiplied in the pediatric population in respect to their inability to primarily care for themselves.

## DOMESTIC AND INTERNATIONAL PERSPECTIVES

There is significant divergence in the capabilities for natural disaster preparedness between the developed world and the developing world. The United States, for example, has developed the infrastructure for responding to disasters at the federal, state, and local levels. The National Disaster Medical System has critical functioning in the assessment of health and medical needs as well as deployment of medical care personnel, equipment, and supplies. It assists with victim identification and mortuary services as well as aiding in patient evacuation and in-hospital care of patients.

Developing countries are more reliant on the international community given their potential limitations of trained personnel, infrastructure, and financial considerations. This may result in delays in the rescue and treatment of ill or injured persons. To varying degrees, international relief efforts respond to the immediate, life-threatening needs of an affected country<sup>2-4</sup> and not to the preparation for disasters. On December 26, 2003, an earthquake measuring 6.5 on the Richter scale caused catastrophic damage to the city of Bam and neighboring villages, with a collective population of approximately 142 000. There were more than 40 000 deaths and tens of thousands of injuries. According to the United Nations Disaster Assessment and Coordination team mission report, this earthquake destroyed 87% of the buildings in Bam and left 80 000 persons homeless. A total of 18 000 buildings in Bam and the surrounding villages were destroyed including 131 school buildings, 3 hospitals, 95 health centers, and 14 rural health clinics.<sup>5</sup> The 2004 Indian Ocean Tsunami resulted in more than 150 000 deaths and eventually required more than \$7 billion in aid and assistance in Indonesia.<sup>6</sup> The 2005 earthquake in Pakistan, which occurred 1 month after Hurricane Katrina, killed approxi-

mately 80 000 people and injured an additional 200 000, of whom half were children.<sup>7</sup> Even more devastating was the 2008 earthquake striking Wenchuan County in China's Sichuan Province. This 7.9 magnitude earthquake directly resulted in infrastructure collapse and damage but triggered more than 12 000 landslides and mudflows, causing flooding. More than 87 000 people were killed (more than 5300 children, most as a result of the collapse of school buildings), 374 000 people were injured, and 15 million people were left homeless. The economic impact has reached more than \$124 billion.<sup>8</sup>

In general, the primary assessments for these types of disasters reveal that the main causes of morbidity are from direct injuries, including fractures from collapse of structures, and the main causes of mortality are traumatic injury and suffocation.<sup>9</sup> The burden of caring for the injured and traumatized patients fall on local health systems that may be damaged themselves. Treatment for acute trauma, emergency surgical interventions, and acute medical life-support activities will likely fully consume the capacity of regional health care systems. These systems may have limited equipment, supplies, and expertise to manage the particular needs of the injured or traumatized child.

## INJURIES AND DISEASES

Infants and young children are especially prone to injuries and diseases after a disaster for a number of reasons. Children are physically closer to the ground and are naturally curious about things around them. For this reason, they may interact with dangerous items including building debris, fallen trees, downed power lines, and bodies of water. They are less able to protect themselves, and their organs are proportionally larger, closer together, and less well protected.<sup>10</sup> As a result, they are highly susceptible to wounds, head trauma, multisystem organ injury, fractures, burns, and drowning. Adolescents may likewise be prone to many of these problems due to their immaturity relative to adults.

Likewise, children are highly susceptible to many diseases including respiratory, gastrointestinal, and skin infections. Children have increased fluid needs proportional to their size and will not necessarily adequately hydrate themselves without adult supervision and encouragement. Access to age-appropriate foods and hydration (ie, infant formula) may be more difficult to obtain after a disaster. Young children are not only particularly prone to dehydration and undernutrition, but they may also be unable

to communicate if they are in distress. Family members, in the setting of dealing with other urgent needs, may not recognize the needs of young children until a crisis develops. In addition, children with chronic medical conditions who are separated from family members may not be able to communicate their medical needs and may thus be undertreated.

Chronic conditions, especially asthma and diabetes, will worsen during these disasters because of missing medications, worsening environmental conditions, and inadequate attention paid to routine management of these diseases. Children with more complex illnesses, especially those hospitalized and requiring ongoing treatment, will have to be transferred to appropriate facilities away from the disaster that can manage pediatric patients.

Lack of adequate housing exposes disaster victims to weather extremes leaving children vulnerable to hyperthermia and/or hypothermia, often within the span of 24 hours. Once outside the family home, access to food and water may be limited. Providing food and water to these families is a cornerstone of preventing new and worsening medical problems.

The treatment of these problems requires personnel who can appropriately evaluate and manage pediatric patients, including physicians, nurses, respiratory therapists, and pharmacists trained in pediatric care. They require pediatric-specific equipment, supplies, and pharmaceuticals.

## DISPLACED FAMILIES

Families with children pose multiple challenges that can be anticipated in advance. Whenever possible, family units should stay together to provide physical, psychologic, and emotional support to one another. If a family member is injured or sick and requires medical attention, special consideration must be given to keeping the family together even if space is limited. If a child is ill, a parent can provide the 24-hour care and attention required that will otherwise not be afforded by the medical staff.

Children separated from their families pose an especially challenging problem. Hurricane Katrina clearly demonstrated the problem of young children unable to properly identify themselves or their parents and families separated by hundreds of miles upon relocation during a massive storm. Systems that can capture physical-identifying data about children before disasters will play an important role in the future. Computer pattern identification tools also have the potential to reunite children and families.

## INFECTIOUS DISEASE DISASTERS

Infectious agents leading to natural disasters are not limited to airborne or contact transmitted diseases. Consider the fervor surrounding large outbreaks of foodborne disease. In early January 2009, the US Food and Drug Administration, along with the US Centers for Disease Control and Prevention issued warnings to consumers of peanut products contaminated with *Salmonella*, originating at a single processing plant. In 2006, clusters of *Escherichia coli* 0157:H7 was traced to contaminated spinach. These warnings led to massive product recalls, media hysteria, and ensuing public appeal for evaluation, assistance, and governmental oversight. Packaged food that has been contaminated (such as with the peanut products) pose a significant risk to children because they are easy to distribute in multiple venues (home, school, daycare settings, vending machines) and are perceived to be safe because they are “factory sealed.” Despite the concern, according to the Centers for Disease Control's Food-borne Active Surveillance Network (FoodNet), over the past decade, there has actually been a substantial *decrease* in the incidence of different bacterial pathogens commonly transmitted through food.<sup>11</sup> The reality of the problem is far less than the generated fear, leading to massive appeals from those concerned, thereby meeting the definition of a “disaster.”

The international crisis caused by the H1N1 pandemic exemplifies how a “natural disaster” may unfold with moderate federal and local governmental involvement and minimal intervention. On April 9, 2009, it became apparent to public health officials in Mexico City that an outbreak of influenza was in progress late in the influenza season.<sup>12</sup> Within a period of weeks, it had spread to the United States, Canada, as well as Europe and Asia. The World Health Organization eventually elevated the pandemic alert level to “Phase 6” (characterized by human-to-human spread of the virus into at least 2 countries in 1 World Health Organization region). Although this outbreak led to thousands of confirmed cases, there have been less than 500 deaths as of August 2009 in the United States associated with this disease. Children are at increased risk of contracting these types of airborne illnesses because they are cohorted in schools and daycare settings. The impact of H1N1 that was placed on the local health care system was extraordinary. Despite recommendations from federal and local health officials that patients with mild illness stay home,<sup>13</sup> the media fervor caused by H1N1 and some inconsistent responses from local public officials resulted

in either a child with a suspected case or with a confirmed case of H1N1 being kept out of school, or the other extreme, a single case leading to an entire school closing. This resulted in patients inundating their primary care providers' office with requests for evaluations and the primary care providers referring patients to local emergency departments (EDs) for testing and/or treatment. This upsurge in patient volume in some EDs triggered hospital "surge protocols." Emergency departments reported visitation rates up to 2- to 3-fold higher than normal, and increased levels persisted for more than a month after the outbreak began. Children's Memorial Hospital in Chicago saw its ED volume double from a May 2008 average of 170 patients per day, with peak daily volumes approaching 400 visits in early May.<sup>14,15</sup> Although this incident was a useful test of many hospitals' crisis response plans (many instituted after the World Trade Center attacks in 2001, but never formally tested), it demonstrated that there is still a significant amount of work that needs to be done in the preparation for a similar but more lethal mass casualty event.

## RECOMMENDATIONS

It is impossible to adequately plan for all types of natural disasters. The scope of the problem far outweighs the financial, physical, and personnel capacities needed to anticipate all potential events and their consequences. What needs careful attention is a generalizable approach to planning for natural disasters and a coordinated effort in the response once these events do occur. These plans need to take place at the local level, in the primary care provider's office, in the schools, and in community hospitals. Local, state, and federal governments must develop the infrastructure necessary to coordinate response efforts. Efforts such as active surveillance of disease can alert health officials of atypical illness patterns that may foretell a coming pandemic.<sup>16-18</sup> Plans for disseminating information to members of the community that inform but do not evoke panic must be developed. Stockpiling of equipment (such as ventilators) in appropriate sizes for all patients must be considered. Using a hypothetical influenza outbreak model, assuming that 35% of the population would be affected, the New York State Department of Health estimated that there could be 93 753 total influenza-related hospital admission with more than 14 000 total influenza patients requiring care in an intensive care unit. It is estimated that more than 7000 cumulative influenza patients would require

ventilatory support during the duration of the outbreak, with more than 2171 patients needing them simultaneously during the peak weeks, which far exceeds the current ventilator capacity of the state.<sup>19</sup> The needs of children who are at higher risk for severe disease, will readily outstrip pediatric intensive care capacity.

In addition to information technology systems and durable medical equipment, consideration must be given to developing a cache of medications. The recent H1N1 outbreak demonstrated that local pharmacies can become overrun early in the pandemic, depleting their supply of antiviral medications such as Oseltamivir. The federal government provided states with hundreds of thousands of courses of the medication from the National Strategic Stockpile; however, these were distributed only to hospitals and health centers. Thus, the "walking well," who were not ill enough to require hospitalization but needed/wanted treatment, could not obtain the medications in their local pharmacy. This resulted in patients adding to the pressures of local EDs and hospitals to provide medication that was being reserved for the critically ill. The need for liquid formulations of medications must also be addressed to fully anticipate the needs of the very young and very old.

In the post 9/11 days, local, state, and the federal governments have made significant strides in the planning for man-made disasters. These preparations have resulted in systems that are useful in the face of natural disasters. The creation of disaster response teams with specific training in pediatrics has been a crucial step. Additional thought is warranted toward active surveillance of diseases in children; increasing the supply of durable medical equipment that are required in the neonatal and pediatric intensive care units and the creation and maintenance of a cache of medications with pediatric formulations should be factored in to the strategic planning for future disaster planning. ☒

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