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OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

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Pediatrics 2006;117;S405-S411

DOI: 10.1542/peds.2006-0099M

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<http://www.pediatrics.org/cgi/content/full/117/5/S2/S405>

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American Academy of Pediatrics

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The National Disaster Medical System Response: A Pediatric Perspective

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The authors have indicated they have no financial relationships relevant to this article to disclose.

A HURRICANE IN New Orleans, Louisiana, was no longer just a threat but a reality. At the New Orleans Louis Armstrong International Airport, a small group of Boston-based National Disaster Medical System (NDMS) physicians met with military officers, who informed us that 5 years ago they were charged with preparation for potential national disasters. A hurricane in New Orleans was 1 of 3 scenarios they predicted. As a nation, as individuals, and as a disaster team we were living that prediction. Although we took care of disaster victims of all ages and disaster-relief workers, for those of us in the field of pediatrics, our focus was on the youngest victims of the disaster.

LONG-TERM PREPARATION

Preparation begins not days but years before a disaster. Teams deployed to areas affected by Hurricane Katrina are part of the NDMS, a federally coordinated system that augments the nation's emergency medical response capacity. In 1984 the NDMS, by declaration of the President, became an agency of the US Public Health Service within the Department of Health and Human Services. It is a public/private partnership between government agencies, Disaster Medical Assistance Teams (DMATs), civilian hospitals, and emergency-response organizations. The role of the NDMS is to provide civilian medical support to the US government for victims of domestic disasters. A national network of teams provides a single integrated medical response to assist state and local authorities with medical care. The first NDMS team was formed in 1986. In March 2003, the NDMS was transferred from the US Public Health Service to the Response Division of the Federal Emergency Management Agency under the Department of Homeland Security.

OBJECTIVES AND ORGANIZATION OF THE NDMS

The NDMS, using government and private-sector resources, is mandated to provide medical response, patient evacuation, and definitive medical care. Specifically, the NDMS assesses health/medical needs; coordinates, mobilizes, and manages teams of medical and management support personnel for medical care, search, rescue, and mortuary services; provides equipment, supplies, and pharmaceuticals; coordinates patient evacuation; provides health surveillance; prioritizes use of health and medical support; and manages relevant congressional affairs, community relations, and public information.

NDMS teams are deployable rapid-response units that deliver immediate short-term medical services until local resources can be fully restored or government, international, or contract resources can provide these services. They are community based and cosponsored by a public or private organization such as a medical center or health- or public service-oriented government agency. NDMS teams may be deployed for local, state, federal, or international disasters or events with potential for disaster and/or may provide medical services in a site devel-

Key Words: Hurricane Katrina, National Disaster Medical System, pediatrics

Abbreviations: NDMS, National Disaster Medical System; DMAT, Disaster Medical Assistance Team; PST, Pediatric Subspecialty Team; IMSuRT, International Medical Surgical Response Team; MA-1, Massachusetts Disaster Medical Assistance Team 1; LSU, Louisiana State University; WJMC, West Jefferson Medical Center

www.pediatrics.org/cgi/doi/10.1542/peds.2006-0099M

doi:10.1542/peds.2006-0099M

Accepted for publication Jan 25, 2006

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 PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275). Copyright © 2006 by the American Academy of Pediatrics

oped to receive victims of a disaster. Teams must have the shelter, food, medical treatment facilities, equipment, and supplies, as well as communication capabilities, to function completely independently for 72 hours.

The goal of the NDMS is to have the capacity to provide care for mass-casualty events within 24 hours of a disaster or emergency. The NDMS may serve as the primary source of medical services or may augment existing local services.

The NDMS teams that provide general medical care are DMATs. Pediatric Subspecialty Teams (PSTs), International Medical Surgical Response Teams (IMSuRTs), and burn specialty teams are specialty DMATs. Other NDMS teams include the disaster mortuary team and veterinary medical assistance teams. The critical functions of DMATs are:

- Triage: initial assessment, prioritization of treatment, and determination of appropriate treatment site.
- Stabilization: medical/surgical resuscitation.
- Definitive medical/surgical care: outpatient acute care and inpatient care for noncritical medical/surgical patients.
- Evacuation: a network of nonfederal acute care hospitals located throughout the United States have agreed to accept and provide care for a predesignated number of critically ill or injured patients.

DMATs can use existing health care facilities, convert intact structures into medical facilities, and/or set up field medical tents with generator power for minor surgical procedures, stabilization of critically ill patients, and routine care including bedside laboratory testing. This decision depends on availability and condition of existing resources as well as demand for services.

PSTs

PSTs have been developed to serve the unique needs of pediatric victims of disaster (Table 1). There are currently 2 deployable PSTs: PST-1 (Boston, MA) and PST-2 (Atlanta, GA). PST-3 (Loma Linda, CA) is in development. Meeting the needs of pediatric victims requires individuals specifically trained in the care of children and pediatric-specific equipment, supplies, and pharmaceuticals. The critical functions of PSTs are the same as for DMATs. PSTs affiliated with and augment a general or specialty team.

Pediatric-specific disaster related considerations include:

- the specific vulnerabilities of children to hazards of disaster;
- unique patterns of injury and illness in children; and
- pediatric-appropriate evaluation and management.

Provision of care appropriate for children requires:

TABLE 1 Pediatric Specialty Team Deployments

Federal Disaster Response Deployments	
September 1995: Hurricane Marilyn, St Thomas, US Virgin Islands	Deployed with DMAT MA-1
October 1998: Hurricane Georges, Caribbean, southeast United States, Gulf Coast	DMAT MA-1 deployment supported by PST-1
January 1998: ice storm, Plattsburg, NY	DMAT MA-1 deployment supported by PST-1
May 1999: Kosovo refugee importation, Fort Dix, NJ	DMAT MA-1 deployment supported by PST-1
September 2001: World Trade Center attack, New York, NY	Deployed with DMAT MA-1/IMSuRT-East
December 2002: Supertyphoon Pongsona, Guam, United States	Deployed with IMSuRT-East
December 2003: Bam earthquake, Bam, Iran	Deployed with IMSuRT-East
August to December 2005: Hurricane Katrina, LA, MS, AL	Deployed with DMAT MA-1, IMSuRT-East
Positioning Deployments	
Summer 1996: Summer Olympic Games, Atlanta, GA	Prepositioned with DMAT MA-1
April 1999: NATO 50th anniversary celebration, Washington, DC	Prepositioned, DMAT MA-1 deployment supported by PST-1
February 2002: Winter Olympic Games, Salt Lake City, UT	Prepositioned with IMSuRT-East

- pediatric-specific trained/experienced health care providers; and
- pediatric-specific equipment, supplies, and pharmaceuticals.

PST-1, established in 1995, is sponsored by Children's Hospital Boston, which provides use of pediatric supplies and equipment. PST-1 is, at a minimum, a 15-member specialty team affiliated with the Massachusetts DMAT (MA-1), which has more than 115 members, and with IMSuRT-East with more than 140 members, sponsored by Massachusetts General Hospital. PST members include pediatric emergency medicine, pediatric critical care, pediatric trauma surgery, general pediatrics, neonatology, anesthesiology, and toxicology physicians and nurses, as well as respiratory therapists and pharmacists.

AUGUST 26 THROUGH 28: 3 TO 1 DAY BEFORE LANDFALL

Each disaster is unique. It was clear that Hurricane Katrina, a Category 5 storm, could create a disaster like no other for which we had ever deployed. The major decision was not if but when and where to deploy. The strategy was to predeploy DMAT teams to multiple sites in safe proximity of the projected storm path for rapid movement into the needed areas as soon as conditions allowed safe travel. Team members were contacted for availability for a minimum of a 2-week commitment. On August 26th (3 days before landfall) the MA-1 cache, which includes field medical tents, logistics and medical equipment, supplies, and pharmaceuticals, was driven to Anniston, AL, by DMAT logistics personnel. The next day (2 days before landfall), MA-1 (including PST mem-

bers) joined them at Fort McClellan in Anniston. Other NDMS teams from throughout the country were predeployed to strategic locations in Louisiana, Mississippi, and Alabama including military bases, Louisiana State University (LSU), the Louisiana Superdome, and Louis Armstrong International Airport.

AUGUST 29: LANDFALL

Plans to deploy other teams, including IMSuRT-East, were underway. As Katrina made landfall as a Category 4 storm, it was the Mississippi Gulf Coast, not New Orleans, that sustained the greatest damage. DMAT teams were ready to provide care as soon as needs could be assessed and the teams repositioned.

AUGUST 30 THROUGH SEPTEMBER 1: 1 TO 3 DAYS AFTER LANDFALL

The change in the path of the storm, flooding in New Orleans, the widespread outage of electricity and communication systems, limited fuel, and impassable roads made assessment and repositioning extremely challenging.

For the first several days, the most emergent need was for search and rescue of victims stranded in their flooded homes and communities. Rescuing children, the elderly, and the infirm was particularly critical because of their susceptibility to dehydration and to hyperthermia from inescapable scorching temperatures during the day and hypothermia from cold, wet conditions at night.

Young children are more vulnerable than adults to serious head and multisystem organ injury resulting from blunt trauma from storm debris. They are less able to protect themselves, and their organs are proportionately larger, closer together, and less well protected. Many storm victims were in need of care for acute illnesses. In addition, untreated chronic medical conditions such as diabetes, pulmonary disease, renal failure, and seizures were quickly becoming acute emergencies.

Also in desperate need of rescue were patients in hospitals damaged by the hurricane. Critically ill pediatric patients, particularly those with serious, often rare diseases required transfer to highly specialized pediatric hospitals that, compared with adult hospitals, are fewer in number.

Unknown at this time were the number of drowning victims; drowning is often a major cause of death associated with flooding, and children are particularly vulnerable. Fortunately, the severe flooding associated with Katrina was geographically limited and the water rose relatively slowly. In most cases, adults had time to ensure the children's safety.

With the evacuation of patients from the most severely damaged areas, the needs for medical assistance continued to shift. Predeployed teams and teams actively being deployed were being positioned not only in Lou-

isiana and Mississippi but also in Texas and other states in which victims were being relocated.

August 30: 1 Day After Landfall

MA-1 was repositioned to Forrest General Hospital in Hattiesburg, Mississippi. The hospital had limited power provided by generators and no working toilet facilities. DMAT members assisted hospital personnel in the evacuation of critically ill patients and treated walk-in patients in the emergency department.

September 1: 3 Days After Landfall

Very early in the morning, the hospital lost all remaining power, so the team assisted in evacuating the remainder of the patients and set up a field medical facility for treatment of outpatients. By the end of the day, power and water had been restored to the hospital, and MA-1 was demobilized from the site.

SEPTEMBER 2: 4 DAYS AFTER LANDFALL

The MA-1 team was repositioned to Kessler Air Force Base in Biloxi, Mississippi. Team members then joined an Ohio DMAT at Biloxi Regional Medical Center that was working in the hospital side by side with hospital personnel (see "Perspectives From a Private Pediatric Practice," pp S359–S364).

SEPTEMBER 3: 5 DAYS AFTER LANDFALL

MA-1 was repositioned to Gulf Coast Medical Center in Biloxi, which now had electricity but limited clean water (see "Perspectives From a Private Pediatric Practice," pp S359–S364). More importantly, many hospital employees, some of whom were unaccounted for, were unable to come to work. The team, using a medical tent along with the emergency department, provided care 24 hours per day. The bariatric chamber anteroom of the hospital was converted into a pharmacy that provided service to storm victims who had no access to their medications. Eleven days after landfall, care was transitioned back to the hospital and its staff.

Also, IMSuRT-East was activated on this day and deployed the next day to LSU in Baton Rouge, Louisiana. Many families from New Orleans had evacuated to Baton Rouge. The Pete Maravich Assembly Center (LSU's basketball arena) had been converted into a medical facility that provided definitive medical care for walk-in patients and stabilization and evacuation for critically ill and injured patients (see "Baton Rouge Pediatricians' Experiences Meeting the Health Needs of Evacuated Children," pp S396–S401). Relief agencies also provided food, clothing, and assistance with housing. Although very busy earlier in the week, needs were now being met with the existing staffing.

As is typical for most disasters, after the first few days, medical needs shifted from patients who required care for injuries sustained during the storm to injuries and

illnesses secondary to the hazardous environment left by the storm. Contaminated water and food and crowded conditions increased the rate of infectious diseases, particularly skin infections, diarrhea, and respiratory illness. Given concerns about postdisaster exposure to tetanus and hepatitis A and B, immunization programs were initiated. In addition, there was an increasing need for medical attention for routine illness and injury unrelated to the disaster.

SEPTEMBER 7: 9 DAYS AFTER LANDFALL

Some members of the IMSuRT-East were repositioned to the Louis Armstrong International Airport (Fig 1). The airport was closed to all commercial flights, and roadblocks restricted ground entrance to agencies and individuals authorized to provide disaster-relief assistance. The airport had been converted into a medical treatment and evacuation center, with NDMS teams occupying the departure level of the airport and the military occupying the baggage-claim level. Triage was set up just inside the entrance to the airport. In the center, there was one tent for patients with emergent conditions (coded as red by disaster-medicine triage convention) and another for victims with urgent and nonurgent conditions (triaged as yellow and green, respectively). A restaurant bar was converted into a pharmacy, and the ground-transportation information desk was used to coordinate air and ground transport of patients who required evacuation to hospitals for definitive care.

Teams slept on cots in baggage carousels. The airplane tarmac was used for food service, and security, showering, and laundry facilities were provided by the military. MA-1 left the airport 19 days after landfall. DMATs from at least 7 other states also provided care 24 hours per day at the airport.

Also, the remainder of IMSuRT-East relocated from LSU to West Jefferson Medical Center (WJMC) just out-

side New Orleans in West Jefferson, Louisiana. Many people in this area had not evacuated, and many who did were starting to return. Relatives from more severely damaged areas were staying with family in Jefferson Parish. There were also large numbers of utility and transportation workers from across the country who were brought in to restore critical services, remove hazardous debris, and repair roads. In addition, military and private security firms were brought into the area to restore and maintain law and order. WJMC, built to withstand severe storms, had sustained minimal damage. The challenge was meeting the needs of an increased patient load with decreased staffing. Many employees were not able to return to work because they or their family members were storm victims. Other staff, who had become homeless, returned to the hospital with their families to work and stay. DMAT and hospital personnel worked together for the most efficient use of their combined resources.

The DMAT set up a medical facility in front of the WJMC that consisted of separate tents for triage, emergent patients, urgent and nonurgent patients, immunizations, and for command, communications, and logistics. Patients arrived by ambulance, by private transportation, and by foot. The majority of patients presented to the DMAT for triage and, if critically ill, were transferred to the emergency department. Stable patients who presented to the emergency department were triaged to us (Figs 2 and 3).

SEPTEMBER THROUGH DECEMBER: 2 TO 15 WEEKS AFTER LANDFALL

DMAT members, working in shifts, provided 24-hour coverage. IMSuRT-East staffed the WJMC DMAT facility from day 11 to day 19 postlandfall. A redeployed MA-1 team took over at the WJMC, providing service for another 14 days. On average, each day during this time



FIGURE 1
DMAT medical tents in Louis Armstrong International Airport (New Orleans)



FIGURE 2
DMAT field tent at the WJMC.



FIGURE 3
Treatment area of the DMAT tent.

period approximately 215 patients were seen in medical tents. Of these, approximately 82% were triaged as green, 14% as yellow, and 4% as red. Approximately 12% were under 15 years of age, and more than half of those were under age 2. Rotating DMAT teams from New York, Minnesota, Arkansas, Texas, California, Tennessee, Florida, and Ohio provided medical care at the WJMC until mid-December.

From October 19 (7 weeks after landfall) through 25th, the MA-1 staffed St Bernard's Parish field medical facility, which was set up on a high school football field. By that time, most of the care was being provided for routine illness and injury.

At each of the DMAT facilities, the majority of patients were adults. Initially, workers represented a significant percent of the patients. As families who had evacuated returned to their homes, the number of patients, including children, increased. Initially, nighttime volume was low because of curfews, but this volume increased as the curfews were lifted. Minor injuries, sustained while inspecting, cleaning, and repairing properties were frequent. Although some injuries were the result of violence, these were very limited in number in our experience.

For children, debris, downed power lines, generators, and animals created a dangerous environment made even more hazardous by disruptions in daily routine and supervision. The most common injuries in children were lacerations and punctures caused by debris. Several children were bitten by animals, many of which were stray pets with unknown rabies status. Many of the wounds were infected, likely because clean water and antibacterial ointment were unavailable. Cellulitis resulting from insect bites was also particularly common in children.

Children were at increased risk of ingestion of contaminated food and water. Because many families were living in new situations, medications were no longer

safely out of reach. Poison ivy was everywhere including on trees, which were being pulverized and burned, releasing allergens into the air. For children, asthma and diabetes were the most common chronic conditions for which families sought medical assistance.

Perhaps our greatest challenge in treating patients was that many of them did not know significant details about their medical conditions, medications, or immunization status. Because families' usual health care providers were not available, many brought their children for routine child care visits, well-child examinations, immunizations, and medication refills for chronic illnesses. Although most victims were coping amazingly well, many understandably experienced psychological stress, and some suffered psychiatric decompensation. For children, this was manifest most commonly as fears about recurrence, separation anxiety, and behavioral disturbances (see "Short-term Impact of a Major Disaster on Children's Mental Health: Building Resiliency in the Aftermath of Hurricane Katrina," pp S448–S453).

We quickly learned about endemic conditions. Limited access to clean water made it difficult to ensure that patients could properly care for wounds, so many patients returned for wound checks and care.

Fortunately, our diagnostic resources were excellent. In addition to our own bedside testing capabilities, which included electrocardiograms, complete blood counts, chemistry panels, urinalyses, pregnancy and rapid streptococcal tests, we had access to hospital laboratory testing and radiologic imaging. We were able to provide definitive treatment for most patients.

Most health care providers worked 12-hour shifts. Given that children have different patterns of injury and illness that require specific approaches to evaluation and management, it is important that teams have pediatric-trained physicians, nurses, and pharmacists. Pediatric-trained health care providers often worked 16-hour shifts and were on-call for the remaining 8 hours. For mental health issues, our team was able to provide some immediate care and referrals for social services, but resources for ongoing psychiatric care were limited.

We had or were able to procure medications to treat most acute conditions and vaccines. Lack of electricity challenged quality control of temperature-sensitive medications and vaccines. The pharmacist had a generator-powered refrigerator, the temperature of which was monitored constantly. For families without access to refrigeration, some medications were a problem. These children were given adult tablets, precut to the appropriate dose by the pharmacist, or capsules with instructions on how to open and sprinkle the capsule contents into food. We did not have large stocks of medications for treatment of chronic illness, but local pharmacies, including mobile pharmacies, filled prescriptions without charge for a few days (see "Providing Primary Care to Underserved Children After a Disaster: A National

Organization Response," pp S412–S415). For young children, in addition to medications, we were able to provide formula and diapers.

Follow-up compliance with return-visit recommendations was outstanding. For children who had missed routine immunizations, we worked with the state to procure the vaccines and give the immunizations and a revised immunization schedule.

Everywhere we went, people were incredibly grateful and appreciative that we were there and for the care that we could give them. For us, it was a privilege to be able to help.

Through the efforts of all the DMAT teams, as of mid-December more than 63 163 patients had been evaluated and treated, and more than 68 654 individuals had been immunized.

LESSONS LEARNED

This disaster, which resulted in a major city being entirely evacuated and shut down for the first time in US history, emphasizes once again the importance of having an organized disaster-relief system. It also taught us about some unfortunate and very real limitations of disaster systems.

1. Effective disaster-relief efforts require plans with contingencies and the elements necessary to implement them.
2. A coordinated effort with integrated communications between local, state and federal governments, as well as civilian agencies, is critical.
3. Infrastructure in the form of ongoing planning, logistics, and security is essential to coordinate and support the medical response.
4. NDMS disaster response requires a highly trained core of individuals from a variety of fields who are available for immediate response and are prepared to work in what are often austere, stressful conditions. Good Samaritans, who are not experienced or trained in disaster medicine, despite their best intentions often hinder the efforts and furthermore require the use of the very resources that they are trying to supplement.
5. Immediate and long-term effects on NDMS providers of long work hours, challenges of caring for patients outside of their specialty, unfamiliar and challenging environments with limited resources, exposure to traumatic events, personal safety, disruption of personal routine, and trying to balance the responsibilities of their personal lives and work at home while deployed should not be ignored or underestimated. It is not uncommon for workers to experience difficulty returning to their routine at home and at work and to experience fatigue and sleep disturbances (see "Pediatrician Self-care After Disasters," pp S454–S457).

The NDMS has developed a demobilization screening for the physical and mental health of team members. It is essential that resources be available for disaster-relief workers while they are on site and when they return home.

6. Children have increased vulnerabilities to the hazards of disasters, different patterns of injury and illness, and unique medical and psychosocial needs during and after a disaster. Individuals trained in the care of pediatric disaster victims are critical to the disaster-response effort. More PSTs are needed to expand the capacity of DMATs to provide pediatric care.
7. Because adults often seek care for their children before or instead of for themselves, it is important for pediatric health care providers to inquire about the health of the adults. These adults, particularly those with young children, are often in the age range and have conditions that pediatric care providers routinely care for.
8. Although more PSTs are needed to expand the capacity of the DMAT to provide specialty care, getting families prepared for disasters is equally important. Pediatricians have the opportunity and responsibility to provide information to families regarding disaster preparedness, especially for children. Specific instructions and plans should be developed for children with common chronic medical problems and those with special needs (a useful form is available at www.aap.org/advocacy/blankform.pdf).
9. Pediatricians should be prepared to provide care for children and families who have relocated and to ensure that care is available for those who do not have financial resources. Many will be without records or knowledge of their medical conditions and treatment regimens. Many will have undergone traumatic changes in their lives, loss of personal resources, and loss of community and social support networks. Children's psychological response may be highly variable in its manifestations and duration. Depression, behavioral disturbances, fears, posttraumatic stress disorder, and phobias are all common responses to disaster.

COMMENTS

As pediatricians, we are uniquely qualified to take care of the needs of the pediatric victims of disaster, making a valuable and lasting contribution to their lives and their families. For those of us who are part of the NDMS, the opportunity to use our expertise to help others during disasters is incredibly gratifying and rewarding.

Unfortunately, we have learned that, even under the best circumstances, a national/international disaster response (especially for a widespread, large-scale disaster) will likely not be adequate. Even when predeployed, it is

difficult, if not impossible, for teams to be on site soon enough to save critically injured victims who require treatment within those first hours. Also, given the huge allocation of financial and human resources required to maintain a national disaster system of the magnitude necessary to respond to large-scale disasters such as Katrina, some may question the appropriateness of such a plan. Local efforts, government and civilian, that include plans to promote and enable self-help must be used to the fullest extent possible.

CONCLUSIONS

The effects of Hurricane Katrina will be felt for years to come. The lessons from Katrina have been painful, and the future for its victims is uncertain in many ways. Unfortunately, what is certain is that Katrina will not be our last disaster. We can only hope that with every disaster we learn from our previous experiences and will have more to offer as a nation, health care providers, and human beings.

ACKNOWLEDGMENTS

This article is dedicated to our families, colleagues, and friends, who support our efforts and make our deployments possible, and to the victims of Hurricane Katrina, whose tragedies and triumphs, courage, and resolve are an inspiration to us all.

We gratefully acknowledge all of the groups and in-

dividuals who so graciously hosted and assisted us throughout our deployments. We also thank Dr Susan M. Briggs (National Disaster Medical System, National Supervisory Officer, Specialty Medical Teams/IMSURT) for her very helpful review of this manuscript.

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