Houston's Medical Disaster Response to Hurricane Katrina: Part 2: Transitioning From Emergency Evacuee Care to Community Health Care

Douglas R. Hamilton, MD, PhD, MSc Eng
Thomas Gavagan, MD
Kieran Smart, MD
Nancy Weller, BSN, DrPH
Lori A. Upton, RN, BSN, MS
Douglas A. Havron, RN, BSN, MS
Avrim Fishkind, MD
David Persse, MD
Paul Shank, MBA
Umair A. Shah, MD, MPH
Kenneth Mattox, MD

From the Baylor College of Medicine, Department of Family and Community Medicine (Hamilton, Weller) and Department of Surgery/Harris County Hospital District Division (Mattox), Houston, TX; Northeastern Medical School, Chicago, IL (Gavagan); FSU College of Medicine, Sarasota, and Department of Family Medicine and Rural Health, Sarasota, FL (Smart); Texas Children's Hospital, Houston, TX (Upton); the Southeast Texas Trauma Advisory Regional Council, Houston, TX (Havron); the Mental Health Mental Retardation Authority of Harris County, Houston, TX (Fishkind); City of Houston's Emergency Medical Services, Houston, TX (Persse); Harris County Public Health and Environmental Services (Shah); and the San Luis Valley Regional Medical Center, Alamosa, CO (Shank).

After Hurricane Katrina hit the Gulf Coast on August 29, 2005, thousands of ill and injured evacuees were transported to Houston, TX. Houston's regional disaster plan was quickly implemented, leading to the activation of the Regional Hospital Preparedness Council's Catastrophic Medical Operations Center and the rapid construction of a 65-examination-room medical facility within the Reliant Center. A plan for triage of arriving evacuees was quickly developed and the Astrodome/Reliant Center Complex mega-shelter was created. Herein, we discuss major elements of the regional disaster response, including regional coordination, triage and emergency medical service transfers into the region's medical centers, medical care in population shelters, and community health challenges. [Ann Emerg Med. 2009;53:515-527.]

0196-0644/$-see front matter

doi:10.1016/j.annemergmed.2008.10.024

SEE RELATED ARTICLE, P. 505.

INTRODUCTION

This article is part 2 of a description of events that took place from September 1 to 20, 2005, in Houston, TX. It is written from the perspective of civilian medical personnel working at the Astrodome/Reliant Center mega-shelter and Catastrophic Medical Operations Center staff. The article describes the unique problems inherent in providing medical care and housing on short notice for as many as 27,000 evacuees presenting with a variety of acute and chronic medical problems. We also present the challenges posed to the regional medical system and the response of the Houston/Harris County community to help displaced evacuees from Hurricane Katrina.

The data presented in part 2 of this article are derived from analysis of hardcopy and electronic patient encounter data (see part 1, "The Initial Medical Response from Texas Trauma Service Area-Q").

CONVERTING THE ASTRODOME/RELIANT CENTER INTO A SHELTER WITH AN ADJOINING COMMUNITY HEALTH CLINIC

After the initial triage and registration of Katrina evacuees from the Gulf Coast into the Astrodome/Reliant Center shelters, medical professionals and support staff from Baylor College of Medicine, the Harris County Hospital District, and Harris County Public Health and Environmental Services were tasked with creating a medical infrastructure to care for the Katrina evacuees and managing volunteer medical staff (1,500 physicians and 1,800 nurses) arriving from across the United States.

Within 48 hours of initial Astrodome/Reliant Center operations, the Katrina Clinic was constructed. This clinic, a

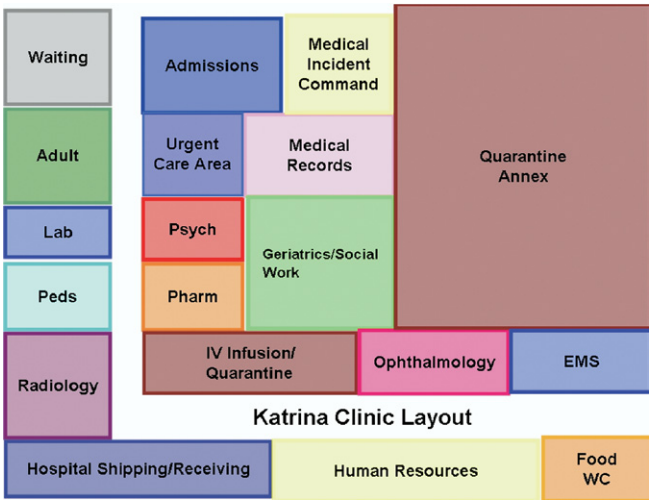

Figure 1. The Katrina Clinic was constructed in the Arena adjacent to the Astrodome. The clinic layout was designed approximately six hours before the first bus arrived and was fully functional before noon the following day. Patient examination rooms and specialty areas were built using local exhibit hall materials; medical supplies were provided by Baylor College of Medicine, the Harris County Hospital District, the Houston Fire Department, CVS Pharmacy, numerous medical supply companies, and many businesses and hospitals throughout the region.

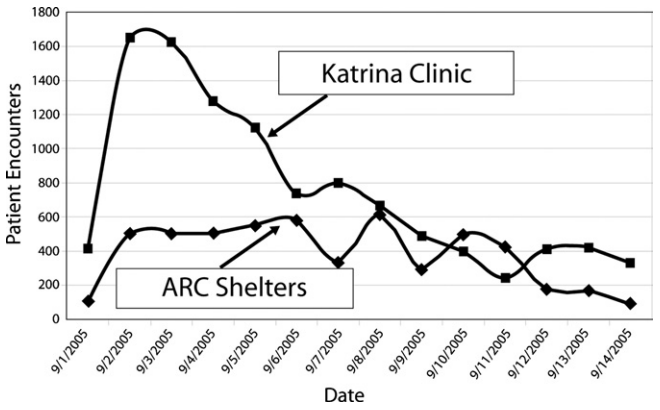

Figure 2. Closure of the shelter treatment sites at night (September 11th) and complete closure caused an increase in clinic encounters (September 14th). The fall in clinic encounters by the end of the first week of Astrodome/Reliant Center operations reflects the reduced level of acuity in patients after initial treatment during the first week. Peak clinic visits are associated with bus disembarkation times when evacuees sought immediate medical attention.

100,000-square-foot state-of-the-art health center, was created with complete laboratory, radiograph, and pharmacy capabilities; dental offices; mental health services[1]; ophthalmology and eyeglass services; and 65 examination rooms with urgent care triage, adult medicine, pediatrics, obstetrics and gynecology, orthopedics, emergency psychiatry, and other specialties (Figure 1).

The bus disembarkation triage sites at the shelters (known as the "yellow lot") were constructed in the parking lot of the Reliant Center Complex. Medical staff assessed evacuees for relocation to the Astrodome, other Reliant Center shelters, the Katrina Clinic, or emergency medical services (EMS) transport to area hospitals. After the first several days when the buses from the Gulf Coast had ceased to arrive, shelter treatment sites were created inside the respective residential areas. These treatment sites were designed to manage minor illness and injury to divert additional patients from overwhelming the Katrina Clinic.

The shelter clinic sites treated approximately 5,500 evacuees during the 3-week response period. During the first week, the average number of patient encounters at the shelter was approximately 20% of the Katrina Clinic volume. In the second week of Astrodome/Reliant Center operations, the Katrina Clinic encounter volume decreased to that of the shelter treatment sites, indicating that patient medical acuity decreased rapidly after receipt of appropriate medical care (Figure 2). Unfortunately, a formal medical encounter form was not used in the shelter treatment sites until 3 days after the arrival of the first bus. Informal registration documents created during these 3 days indicate that patient visits exceeded 500, and these high numbers continued during days 4 through 5, when gastrointestinal symptoms peaked.

Figure 2 shows an inverse relationship in incidence rates between the shelter treatment sites and the Katrina Clinic during days 12 and 13 (September 13 and 14), as the shelter treatment sites closed and the evacuee population relocated to Harris County. Patient acuity in the shelters and Katrina Clinic seemed to increase because the more medically challenging patients chose to remain in the Astrodome/Reliant Center or required placement in assisted-living facilities. This became more apparent as the population inside the shelter dwindled to 1,500 after the 14th day (September 15).

Of the evacuees treated at the 2 shelter treatment sites, 75% were assessed immediately and discharged back to the shelter. Although the majority required basic care, 14% were discharged without over-the-counter medications or procedures (eg, these evacuees required only blood glucose checks or assistance with insulin self-administration). Fifteen percent of the encounters were referred directly to the Katrina Clinic for treatment of more serious illness or injury, and 10% were referred directly to the clinic pharmacy for prescriptions or refills.

The sex distribution of evacuees seeking treatment in the 2 shelter sites was 52% and 48% for female and male evacuees, respectively. At the Katrina Clinic, 55% of patient encounters were female patients; 45%, male patients. Figure 3 presents the age distributions of the registered Astrodome/Reliant Center population at its peak and that of evacuees treated at the shelter care sites, the Katrina Clinic, and the Catastrophic Medical Operations Center (see part 1) EMS transfers which were coordinated through the Regional Hospital Preparedness

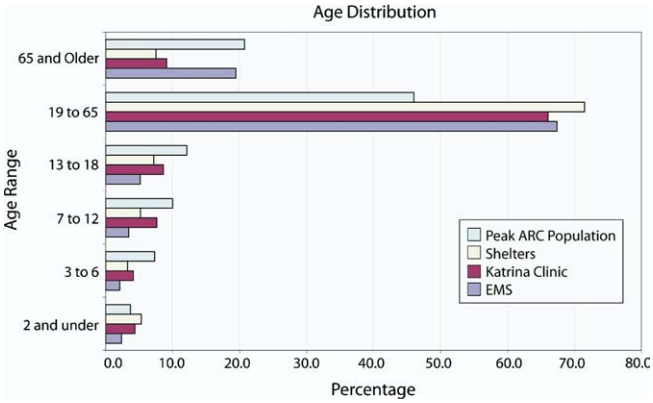

Figure 3. Age distribution of Astrodome/Reliant Center patients. The smaller proportion of elderly presenting to the shelter treatment sites and the Katrina Clinic may be explained by the significant proportion of EMS-transported elderly. [It should be noted that the registered Astrodome/Reliant Center population data are limited at best and should be considered with caution especially from a comparative perspective.] *ARC,* Astrodome/Reliant Center.

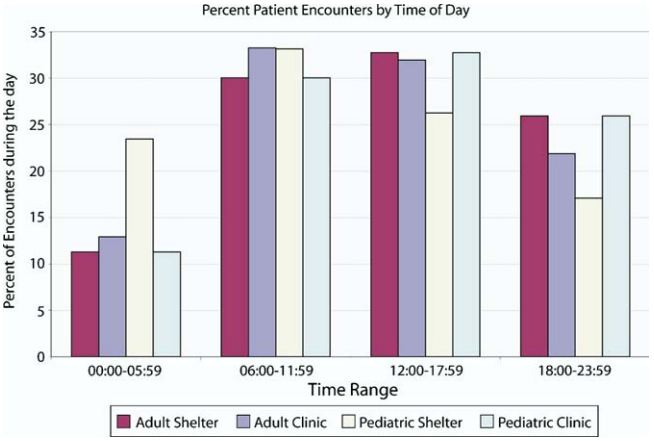

Figure 4. Most treatment sites experienced similar proportions of patient encounters per time interval with the exception of pediatric shelter visits between midnight and 6:00 am. Note a decrease in pediatric visits between 6:00 pm – 12:00 am when parents attempted to settle children; after midnight, parents appear to have used the pediatric shelter clinics more frequently.

Council. Evacuees aged 19 to 65 years represented a greater proportion of visits to the medical facilities. The registered Astrodome/Reliant Center population database acquired by the Red Cross during bus disembarkation was based on the date of birth of 24,082 evacuees. We estimate that as many as 5,000 evacuees were not registered.

Comparisons of the demographic data should be viewed with caution because of the overwhelming nature of Astrodome/Reliant Center's emergency response, possibly resulting in imprecise results.

Of particular interest was the large population of elderly individuals (65 years and older), who represented approximately 20% of the total shelter population but only 9% of patient encounters at Astrodome/Reliant Center medical facilities. The elderly represented a proportionately larger population of EMS transports out of the Astrodome/Reliant Center to Trauma Service Area-Q regional hospitals. The elderly may not have been able to seek help or may have been proactively relocated to outside facilities by Adult Protective Services. Presenting a significant challenge to shelter medical staff, the elderly often needed to be escorted from their cots, located on one of the 4 floors of the Astrodome, to a protected area where Adult Protective Services could assist them. Whenever possible, Astrodome nighttime lighting was dimmed at 11 PM at lockdown; however, many elderly had "sundown syndrome" because of the brighter lighting required by fire regulations. Children younger than 2 years represented 4% of the shelter population (utilizing limited data sources as above). Most of the pediatric visits to the shelter treatment sites occurred in the evening, when parents had trouble settling their children in bed (Figure 4).

Treatment of Illness and Injury Observed at the Katrina Clinic and the Astrodome Shelter Treatment Sites

During the 3 weeks of Astrodome/Reliant Center operations, evacuees were treated at one of the 2 shelter treatment sites and discharged if their condition was minor. Most chronic medical complaints presenting to the shelter treatment sites reflected the socioeconomic status of a significant portion of the population who were, in many cases, uninsured or low income[2] (see part 1, Table). Many evacuees reported a history of diabetes, hypertension, chronic obstructive pulmonary disease, asthma, arthritis, depression, schizophrenia, anxiety, seizure disorders, hepatitis C, HIV, and drug or alcohol abuse and withdrawal. In many cases, evacuees had no medications on arrival, had inconsistent medical care before Katrina, or their medical condition had grossly deteriorated after several days of exposure to the sun, extreme heat and humidity, or unsanitary floodwaters or after the difficult transport from Louisiana to Texas.

Table 1 compares the distribution of medical conditions of patients transported by the Catastrophic Medical Operations Center to Trauma Service Area-Q regional medical facilities, the Astrodome/Reliant Center shelter treatment sites, or the Katrina Clinic. Notable are the remarkably similar distributions (except for respiratory complaints, in which Catastrophic Medical Operations Center transfers were found to have 15% less than the clinic or shelters). Acute respiratory conditions, skin conditions, and gastrointestinal disturbances were among the most common diagnoses, representing more than 50% of the illness treated at the Katrina Clinic (Figure 5).

Injury

The breach of the New Orleans levees and the rapid flooding from Katrina's heavy rains developed rapidly, stranding

Table 1. Distribution of medical conditions seen at the various medical treatment sites within the Astrodome/Reliant Center.

	Shelters		Clinic		Catastrophic Medical Operations Center	
System	**Encounters**	**% Diagnosis**	**Encounters**	**% Diagnosis**	**Encounters**	**% Diagnosis**
Circulatory system	321	6	1,178	10	149	14
Digestive system	871	17	1,875	16	210	19
Endocrine, nutritional and metabolic, immunity	250	5	626	5	95	9
General medical and miscellaneous	366	7	578	5	148	14
Gynecology and complications of pregnancy, childbirth, and puerperium	119	2	659	6	51	5
Mental disorders	78	1	321	3	65	6
Musculoskeletal system and connective tissue	455	9	838	7	93	9
Nervous system and sense organs	460	9	891	7	90	8
Respiratory system	1,503	29	3,257	27	110	10
Skin and subcutaneous tissue	824	15	1,684	14	76	7
Total	5,247	100	11,907	100	1,087	100

residents in their homes, on their rooftops, and in shelters. This population of displaced persons was observed to be different from the victims of other types of natural disasters—earthquakes, for example—in which traumatic injuries and death are often more prevalent. Generally, floods have a slow onset and generate displaced populations requiring disease surveillance, case detection, and shelter accommodation.[3,4]

Katrina-related injuries consisted of mostly minor trauma, with some more serious cases among about 1,100 evacuees treated at the Katrina Clinic; an additional number of very slight injuries were treated at the 2 shelter treatment sites. Another 50 patients with serious injury requiring EMS transport were taken to Houston and Harris County medical facilities.

Injury morbidity observed at the Astrodome/Reliant Center was similar to that observed after many other hurricane-related flood disasters, including some major injuries (eg, broken bones),[5,6] but mostly minor injuries (lacerations and punctures caused by broken glass, nails, and other postflood debris).[6] Blunt trauma, also observed in other flood disasters, was reportedly due to structural collapse and falling objects, as well as wind- and water-strewn debris.[7] Other mechanisms of injuries commonly sustained in hurricane-related floods that were also reported by Katrina evacuees included insect stings and animal bites[5]; assaults; stab wounds; strikes by object/person; falls from buildings, stairs, roofs, and wheelchairs; overexertion injuries; unspecified accidents; motor vehicle crashes; and even a self-inflicted wound in one case of a suicide attempt.[8-11] Data from 4 parishes in and around New Orleans during Katrina's aftermath reported similar injuries (eg, falls, bites/stings, toxic exposures/poisoning, cuts, blunt trauma, burns, environmental exposures).[11]

Some musculoskeletal sprains, strains, and other trauma sustained by Katrina evacuees required treatment by physicians with expertise in physical medicine or orthopedics at the Astrodome/Reliant Center. Retrospective chart analysis of Astrodome/Reliant Center electronic medical records was conducted by Chiou-Tan et al[12] to examine date of visit, age, sex, ethnicity, and physical medicine and rehabilitation diagnosis category. Most frequent were swollen feet and legs (22%), leg pain and cramps (17%), and neck and back pain (10%). The majority (75%) of physical medicine and rehabilitation conditions (239 patients with 292 conditions) presented in the first week, emphasizing the importance of providing treatment for minor trauma and injury in the initial phase of a disaster response. Chiou-Tan et al[12] analyzed data from only the Katrina Clinic, and they observed that more than 1,000 patients were treated at the shelter treatment sites for skin and musculoskeletal disorders; the majority of these were Katrina related (Table 1). Unfortunately, shelter treatment site encounters were not coded into diagnostic groups, preventing subgroup analysis. The Katrina Clinic may have treated only patients referred from the shelter treatment sites with a presenting complaint or secondary diagnosis of trauma.

For community planning purposes, the majority of clinic encounters involved mostly primary care–related medical specialties (internal medicine, pediatrics, psychiatry, and geriatric medicine) and very little trauma support.[12,13] This finding resembles the medical encounters documented after Hurricanes Andrew (Florida),[14] Frederick (Mississippi and Alabama),[15] and Elena (Mississippi).[16]

During the entire Astrodome/Reliant Center disaster response and Katrina Clinic operations, a total of 12,535 patient encounters were recorded (of which 1,276 were for administrative purposes only and 4,791 were repeated visits). Prescriptions written for 9,215 patients numbered 16,622. During Katrina Clinic operations, 382 radiographs and 155 ultrasonograms were performed, and the Harris County Public Health and Environmental Services and Harris County Hospital

District administered 13,109 vaccinations. Finally, mental health professionals conducted approximately 4,300 interventions.

Other Services

In the second week of the Astrodome/Reliant Center's operations, eye and dental care facilities were added to the Katrina Clinic. Initially, Katrina Clinic pharmacy services were arranged by courier from the Harris County Hospital District pharmacies, using Harris County Hospital District pharmacy personnel; however, this arrangement was soon replaced by the rapid construction of an on-site CVS pharmacy integrated within the Katrina Clinic. Narcotic prescriptions were restricted and distributed only as clinically indicated, such as for cancer patients requiring pain control.

Other Challenges

When the Federal Emergency Management Agency announced debit card distribution and housing opportunities, an evacuee queue lasting several hours resulted. In many cases, young mothers stood in line outside the Astrodome for hours in the sun. Support staff, including pediatric nurses and social services personnel, were deployed into these lineups because mothers did not want to lose their place in line while changing diapers and rehydrating children with formula/electrolyte-rich drinks. Special considerations were put into place for the elderly and disabled (eg, those in wheelchairs were moved to the front of the queue). At least 10 Red Cross workers were used for logistical resupply of medical and pediatric materials, and National Guard, Texas Rangers, or Houston Police Department usually escorted the personnel during these activities. Later, queues were conducted indoors and improved logistic support was provided.

Evacuee Effect on the Harris County Hospital District's Resources

More than 245,000 Gulf Coast residents evacuated to Houston,[17] and many sought medical care at regional hospitals or Harris County Hospital District hospitals or community health clinics. During the calendar year of Katrina (2005), the Harris County Hospital District experienced 42,486 hospital admissions, representing 239,694 patient-days (average length of stay of 5.82 days), 166,204 emergency visits, and 944,288 (approximately 18,000/week) patient visits to the Harris County Hospital District's 11 community health clinics. Katrina evacuees, who consumed 16,000 patient encounters with Harris County Hospital District staff inside the Astrodome/Reliant Center and 1,100 EMS transfers, affected Harris County Hospital District Community Health Program resources district-wide. The projected Harris County Hospital District community clinic patient load for 2005 was an increase of 3,000 from August to September; however, the actual patient load decreased by 13,000, a change similar to the total Astrodome/Reliant Center Katrina Clinic encounters. This acute 15% decrease in Harris County Hospital District community health clinic visits during September 2005 likely represents the effect of Astrodome/Reliant Center activities on the available Harris County Hospital District physicians, nurses, and other staff who were pulled from their regular duties to provide care at the various Astrodome/Reliant Center treatment sites.

One month after Hurricane Katrina (October 2005), Harris County Hospital District clinic visits increased 15% to 90,039 from 77,981 a year earlier (October 2004). This increase likely was due to the reopening of community health clinics to service cancelled appointments during Houston's Hurricane Rita evacuation and new residents, mostly Katrina evacuees, requiring Harris County Hospital District community health services. Compared with 2004, the November 2005 Harris County Hospital District encounters also increased by 12% but returned to 2004 levels in early 2006. (Fall 2006 encounter data are not useful because Harris County Hospital District community clinics transitioned to an electronic patient record that globally decreased encounter rates for several months as medical personnel learned to use the new system.) Data from 93 non–Harris County Hospital District Texas Trauma Service Area-Q institutions (see part 1) that treated Katrina evacuees have not yet been acquired.

After the Katrina Clinic closed on September 15, 2007 (see grey bar, Figure 5), the new evacuee registration rate observed in Harris County Hospital District community clinics and hospital inpatient/outpatient facilities increased but also became cyclical. This may have been due to the closure of Harris County Hospital District clinics during the weekends and the reluctance of some evacuees to use the 2 Harris County Hospital District hospital emergency departments, which had substantial waiting times. The number of new patient registrations in the Harris County Hospital District community health clinics increased by 200% after the Katrina Clinic closed, showing that evacuees continued to depend on Harris County Hospital District community health resources after the Astrodome/Reliant Center's closure. Because many evacuees did not return immediately to their Gulf Coast homes, this metric to estimate new patients may underestimate new Harris County Hospital District patients because evacuees whose addresses became local also became indistinguishable from the general population.

Management and Organization of the Astrodome/Reliant Center

The large scale of the Katrina Clinic and Astrodome/Reliant Center Medical Branch Operations required an extensive management structure to handle clinical, logistic, and communication issues. This was done under the Unified Area Command's Medical Branch Operations using National Incident Management Systems principles, led by Harris County Public Health and Environmental Services and Harris County Hospital District. The clinical staff was provided by the Harris County Hospital District, in coordination with the Baylor College of Medicine and other community partners (eg, Texas

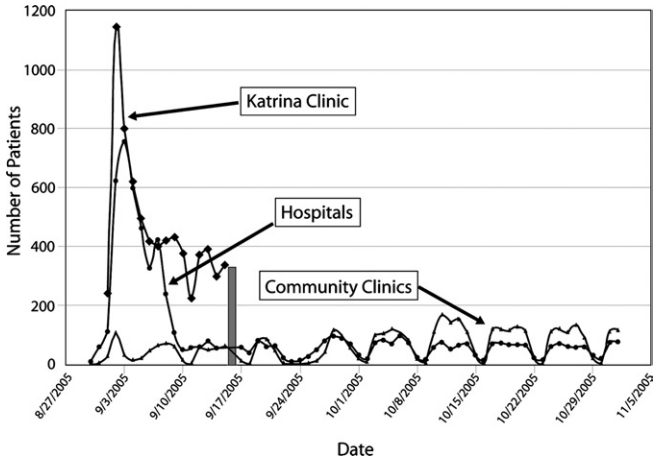

Figure 5. Harris County Hospital District encounters. The acute rise in encounters experienced at Astrodome/Reliant Center is seen with the arrival of the buses (diamonds) and is sustained at several hundred per day after bus disembarkation was complete. The closure of the clinic (grey bar - September 15th) caused an increase in community clinic encounters (triangle) within the next two weeks. Some of this increased clinic activity was for prescription refills since the Astrodome/Reliant Center pharmacy only dispensed one month's supply of medications. Note an abrupt decrease in Harris County Hospital District hospital admissions (circles) after bus disembarkation was complete and Norovirus was contained within Astrodome/Reliant Center. Trauma Service Area-Q non-Harris County Hospital District hospital admission data is not available; most hospital admissions from Astrodome/Reliant Center were tracked by CMOC and are represented in the Astrodome/Reliant Center EMS transfers (see Part 1 figure 2).

Children's Hospital). For example, setting standards for care and checking volunteers' licensing credentials was a critical process in the early days of Astrodome/Reliant Center operations. During the 3 weeks of Astrodome/Reliant Center operations, more than 2,800 medical volunteers worked with 60,003 civilian volunteers to support Astrodome/Reliant Center operations.[17] Approximately 10 groups of well-meaning medical providers opened unauthorized clinics inside the shelters; however, to ensure quality of care, these facilities were removed or assimilated into authorized operations. Several cases of expired, suspended, or fraudulent medical licenses were also documented. Many medical volunteers were not trained as primary care providers and lacked community health care experience; therefore, the allocation of tasks to their appropriate skill sets was critical. In one instance, a group of Austrian medical providers arrived to provide services, requiring verification of licensing and medical credentials. Most foreign medical providers were given tasks that did not require malpractice coverage or medical privileges. Several volunteer physicians and nurses who consistently failed to work within the established command and control structure were removed thanked for their hard work and released from further shifts. A significant advantage was the use of physicians and nurses who had trained at or worked within the Harris County Hospital District Community Health Program and were comfortable treating community health populations similar to the evacuees.

By the end of the first week, the Katrina Clinic evolved into a community health center, with administrative directors from the 11 Harris County Hospital District community health centers rotating to manage oversight. In the second week of Astrodome/Reliant Center operations, the standard operational policies and procedures from the Harris County Hospital District Community Health Program were implemented, not so much through managerial fiat, but through recognition that these processes worked best in what had now become Houston's newest and largest "just in time" community health center.

In most nondisaster medical facilities, formal organizational structures with legal/regulatory controls and information infrastructure operate with a formal chain of command offering knowhow and resources. The true challenge was establishing services early. This was almost entirely dependent on community health professionals who had little or no training in disaster response command hierarchy. In the early hours of the Katrina disaster response, a loose organizational medical structure and chain of command was established, and all medical teams were compelled to adapt to the dynamic circumstances. Unfortunately, in the first 2 chaotic days of Astrodome/Reliant Center's operations, each link in the chain operated somewhat autonomously because of communication failures among the shelter and clinic medical providers. This was not surprising, given the Astrodome/Reliant Center's size, scope, and rapid implementation (see part 1). Within 3 days, a medical command hierarchy that could effectively communicate with the Astrodome/Reliant Center Unified Area Command was established, and management by objectives was initiated, whereupon instructions came down in the form of desired end states, such as "open an OB/GYN service." Those at the operational level were responsible for finding space, furnishings, supplies, and staff to initiate this service. In several cases, through spontaneous social networking, physician and nursing staff, heretofore strangers, self-organized around an issue, determined the requirements, and delegated and accepted assignments. A sense of personal honor and group loyalty added weight to the individual recognition of need and the sense of obligation to those in need.

Twice daily, Harris County Public Health and Environmental Services led the Astrodome/Reliant Center Medical Branch Operations' briefings at the level of the Katrina Unified Area Command, whereas Harris County Hospital District handled the Astrodome/Reliant Center medical staff briefings to inform senior physicians/nurses about policy decisions and overall patient care changes ordered by the Unified Area Command. In time, this management structure provided control and prompt decisionmaking to the Astrodome/Reliant Center.

After completion of evacuee bus disembarkation and medical triage, the Astrodome/Reliant Center medical response transitioned to operations similar to those of a large community health clinic. The transition from an improvised medical disaster response to a well-organized health clinic occurred much more easily than anticipated. Very important to the success of this transition were the Astrodome/Reliant Center first medical responders who were also employees of the Harris County Hospital District Community Health Program; these providers easily switched from "emergency response" mode into "a day at the clinic" mode.

Table 2. Number of diagnoses per encounter.

Number of Diagnoses per Encounter	Katrina Clinic, %	Shelter Triage, %
1	3	72
2	32	22
3	29	5
4	10	1
5	11	None
6	4	None
>6	2	None

Diagnoses per patient encounter are greater at the Katrina Clinic, suggesting increased patient acuity. The lesser number of diagnoses per patient encounter at the shelter triage sites indicates that lower-acuity patients were treated in this setting, most likely preventing the Katrina Clinic from being overwhelmed.

Ethical and Legal Considerations

Evacuees lived in the shelters until more permanent housing within Houston/Harris County and surrounding areas was made available. Although the shelters served as evacuees' "homes," the concepts of privacy and confidentiality were difficult to define or enforce. The shelters provided for the activities of daily living of a diverse group of evacuees who had lost possessions and, in some cases, family members. The ability to provide comfort and social support in such a large community of beds was difficult. Unified Area Command Medical, Harris County Public Health and Environmental Services and Baylor College of Medicine considered shelter beds as medically private spaces. In addition, Medical Branch Operations also made clear to other partners that the Astrodome/Reliant Center and other shelter medical areas should not be filmed, etc., unless filmmakers were under the strictest of escorts. Colored wrist bands were used to control evacuee, volunteer, and visitor access to the shelter areas and Katrina Clinic.

Media access to the shelters presented another problem to medical providers attempting to preserve the anonymity of shelter residents/patients. A total of 678 reporters and photographers from 16 countries registered at the Astrodome/Reliant Center during its 3 weeks of operations. Although bus disembarkation sites were completely secured from the media and journalists found in this area were apprehended by Houston Police Department personnel, television crews were allowed to set up studios inside the shelters, with the approval of the Astrodome/Reliant Center Unified Area Command. In a nighttime incident in the Astrodome, a national talk show crew was threatened with eviction because they refused to confine their screen shots to panoramic views. On several occasions, the media attempted to interview evacuees inside the shelter medical treatment areas and photograph nonambulatory Astrodome/Reliant Center evacuees tending to personal hygiene at their cots. In a few cases, EMS transports leaving the shelters with critically ill patients experienced difficulty when large crowds of celebrity-filming cameramen and reporters blocked corridors and vehicle ramps and refused to move. In several circumstances, law enforcement was called to clear a path for EMS. Because celebrities, politicians, and media representatives frequently attempted to interview and photograph patients in shelter treatment sites, a combination of law enforcement officers from various agencies (the Houston Police Department, Harris County Sherriff's Department, etc) were used to control access to these areas.

As buses continued to arrive and the sheltered population grew, law enforcement and fire (including the Houston Fire Department and Harris County Fire Marshal) were required to ensure a safe environment for thousands of evacuees, workers, and volunteers.[1] Law enforcement was tasked with the security of roadways, parking lots, portable automatic teller machines, and walkways within the Astrodome/Reliant Center, as well as shelter and clinic security.[1] Evacuees were allotted free Greater Houston Metro passes for transport outside of the Astrodome/Reliant Center. Metro buses were also used to shuttle hundreds of evacuees per hour between the Katrina Clinic and various other Astrodome/Reliant Center shelter sites.

Despite the problems encountered in the shelter areas, Health Insurance Portability and Accountability Act (HIPAA) compliance was strongly enforced in the Katrina Clinic. Patient privacy and dignity was well maintained by the construction of individual examination rooms and secure access procedures for the electronic medical record. Unfortunately, at the shelter medical treatment sites, individual examination rooms for private medical encounters were not constructed, allowing passers-by to observe patient treatment in some cases. Although the Katrina Clinic was designed to be a fully functional community health clinic, the shelter medical treatment sites were not designed as medical treatment sites. In some cases, the medical staff who were unfamiliar with family medicine–based community health care environments provided a level of care much higher than that of a "first aid station" (ie, supplier of over-the-counter medicines or area of triage). This was not intended by Medical Branch Operations. The triage sites were tasked to refer patients needing higher levels of care to the Katrina Clinic or to the Catastrophic Medical Operations Center for transport to area hospitals (Table 2). At one of the first aid stations, a makeshift dialysis unit was set up, raising the question of privacy and medical appropriateness of care for this setting. These incidents were handled by Medical Branch Operations personnel to remove unauthorized or inappropriate medical services.

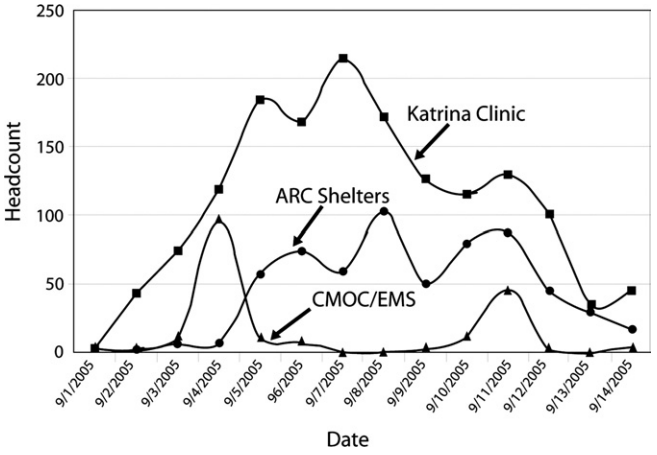

Figure 6. Symptoms of nausea, vomiting and diarrhea in Astrodome/Reliant Center shelters, clinic and EMS transfers. The Catastrophic Medical Operations Center noticed a peak in symptoms of gastroenteritis on September 4th whereupon patient transport into Trauma Service Area-Q was stopped. These symptoms were mostly caused by Norovirus and required isolated re-hydration.

Disease Surveillance and Response

On September 4, 2005, the second day of Astrodome/Reliant Center clinical operations, pediatric and adult cases of nausea, vomiting, diarrhea, and abdominal pain associated with gastroenteritis were observed (Figure 6). Using the Medical Branch Epidemiology Task Force personnel, who were monitoring the chief complaints of patients presenting to the Astrodome/Reliant Center Katrina Clinic and additional surveillance information from "cot-to-cot" surveys in the shelter residential areas, an unusual cluster of gastrointestinal symptoms was observed. Using reverse transcription–polymerase chain reaction on some of the stool samples revealed the causative organism, later identified as norovirus.[18,19] This was the sole enteric pathogen identified, but multiple strains were involved.[20] According to the small sample size, Medical Branch Operations was unable to confirm that all gastrointestinal symptoms were caused by norovirus, but the clinical presentation of most recorded cases was consistent with this pathogen. During the next several days, there was a significant increase in evacuees presenting with gastrointestinal symptoms both to the Astrodome/Reliant Center Katrina Clinic and those transported to area hospitals. As a result of the increasing number of patients presenting with such gastrointestinal symptoms, Medical Branch Operations, in coordination with Katrina Clinic medical staffing, established an isolation site for recovery from illness for affected evacuees. Harris County Hospital District encounter records indicate that as many as 2,000 Astrodome/Reliant Center evacuees were affected with gastroenteritis symptoms compatible with norovirus.

During September 2 to 12, approximately 14% of adult visits to the Katrina Clinic and 28% of pediatric visits were for symptoms consistent with acute gastroenteritis (abdominal pain, nausea, vomiting, or diarrhea); on peak days, these figures reached 21% and 40%, respectively.[18] It is unclear how many of these were attributable to norovirus because of the reasons stated above. Previous studies have published lower incidence rates, but they did not consider lone abdominal pain as a presenting complaint of this pathogen.[18,20] Transporting these patients outside the Astrodome/Reliant Center would have doubled EMS transfers and could have spread the infection outside of the center. A joint decision to isolate and treat affected individuals on site at the Astrodome/Reliant Center was made by the Medical Operations Branch and the Catastrophic Medical Operations Center. Nightly for 2 weeks, Medical Branch Operations, through its Epidemiology Task Force's utilization of other staff and volunteers, went "cot to cot" around shelter facilities, monitoring symptoms such as cough, vomiting, diarrhea, abdominal pain, and fever. These symptoms were tallied nightly in a database made available the next morning to Medical Branch Operations for decisionmaking. By tracking these presenting gastrointestinal symptoms and monitoring trends for other symptoms among the shelter evacuee population, this systematic epidemiologic surveillance was responsible for observing the initial shelter cases of norovirus.

Under Unified Area Command and Medical Branch Operations oversight, the Katrina Operations Joint Information Center[17] engaged in an intensive public outreach campaign to provide banners, posters, and newsletters to shelter areas, so that evacuees and responders alike would be reminded of the importance of hand washing. The Red Cross was also helpful in encouraging global hand washing. Hundreds of Red Cross workers performed hand-wash activities for shelter residents under the direction of the shelter treatment site medical directors. This practice was performed successfully many times in the Astrodome, which held the majority of evacuees, and where approximately half the gastroenteritis symptoms were observed.[20]

Patients with dehydration as a result of the norovirus outbreak were rehydrated in a separate isolation area and then transferred to a large quarantine area for 2 days after cessation of symptoms (Figure 1). Even though good infection control principles and isolation of affected individuals were implemented, the quarantine area was initially open to symptom-free family members of affected patients. Over time, medical personnel learned that law enforcement had begun enforcing a more stringent form of isolation in which patients' family members were also not allowed to leave the area, even if asymptomatic. Medical Branch Operations eventually worked to "loosen" these restrictions on family members because of concerns about isolating those that had already lost loved ones to the hurricane and its aftermath. This relaxing of restrictions was supported by the fact that norovirus outbreaks in hospitals or other clinical settings can often be controlled by sending patients home to recover. Unfortunately, there were no homes, except the shelter, in which the Astrodome/Reliant Center's

evacuees could recover, and these were the very areas under Unified Area Command protection from those afflicted with gastrointestinal illness. Consequently, family members were permitted to stay in the isolation area with the affected patient during recovery. In addition, early in the Astrodome/Reliant Center response, large drums of ice containing cans and bottled beverages were installed in shelter areas; after norovirus symptoms were observed in the Catastrophic Medical Operations Center EMS transfer rates, this possible vector of disease was removed. These modalities—epidemiology surveillance, patient transport trending, provider clinical care and attention, isolation, hand washing, public information campaigns, and eventually the emptying of the shelter areas to decrease crowded conditions—led to the eventual containment of the gastrointestinal outbreak. In total, as many as 2,000 may have been affected by this outbreak.

Tracking of Evacuees and Family Reunification

The Catastrophic Medical Operations Center, coordinated by the Regional Hospital Preparedness Council, maintained an extensive patient database, logging EMS patient transports into health care facilities[21]; however, these data were not intended for evacuees attempting to find family members. In many cases, treating physicians were not aware of the disaster exceptions to HIPAA regulations and the Catastrophic Medical Operations Center patient tracking capability. On September 2, 2005, to facilitate medical care and the identification/location of displaced family members, the United States Department of State released a Privacy Rule bulletin about the sharing of patient information in disaster relief efforts: "Health care providers can share patient information as necessary to identify, locate and notify family members, guardians, or anyone else responsible for the individual's care of the individual's location, general condition, or death. The health care provider should get verbal permission from individuals, when possible; but, if the individual is incapacitated or not available, providers may share information for these purposes if, in their professional judgment, doing so is in the patient's best interest."[22]

Unfortunately, no single database or mechanism to provide evacuee or patient location information existed at the Astrodome/Reliant Center. This situation resulted from the abrupt arrival of some 27,000 evacuees, thus overwhelming the Red Cross's ability to "check in" evacuees. Because such information was not recorded at the initial intake, no database existed that could locate all evacuees. Therefore, Astrodome/Reliant Center and federal, state, and county authorities were referred directly to the Catastrophic Medical Operations Center to obtain this information, which was limited to the EMS transfers within Trauma Service Area-Q.

Reestablishing family and community links became an important priority at the Astrodome/Reliant Center. Because the Red Cross was unable to perform the registration of evacuees upon arrival at the shelters, the process of family reunification was greatly assisted by the ingenuity and resourcefulness of the evacuees themselves, who posted handwritten notes on the Astrodome/Reliant Center's walls. Within 48 hours of the Astrodome/Reliant Center's opening, a large bulletin board was saturated with thousands of personal notes containing contact information of those attempting to locate lost family members. This expanse of notes was unwieldy and soon replaced by an alphabetic last-name system situated around the perimeter of the shelters, greatly increasing the ability of evacuees to locate one another. Seven days after the commencement of Astrodome/Reliant Center operations, a Web-based query system was used and Harris County Hospital District and Red Cross personnel helped those who could not operate a computer.

The Astrodome/Reliant Center also installed hundreds of free landline telephones, which helped reduce evacuee cell telephone traffic. Because dedicated emergency communication assets were not ubiquitous, the Medical Branch Operations had twice-daily "runners" gather information related to patient care and logistics from all shelter treatment sites and the Katrina Clinic. Unified Area Command radios were given to Astrodome/Reliant Center medical command staff inside the Katrina Clinic; however, the latter were unable to communicate with the hundreds of civilian physicians and nurses under their command in the Katrina Clinic and shelter treatment sites.

Difficulties With Providing Mental Health Care

During the Astrodome/Reliant Center response, 570 mental health professionals treated more than 4,300 individuals with mental health concerns inside the shelter areas.[1] Many Katrina evacuees arrived at the Astrodome/Reliant Center with symptoms of acute stress disorder. Others with major mental disorders—schizophrenia, bipolar disorder, and major depression—arrived grossly psychotic or acutely suicidal or violent. In some cases, patients had been without their psychiatric medications for days to weeks and were on the verge of acute episodes of psychosis. Several mental health agencies, including the Baylor College of Medicine Department of Psychiatry, the Mental Health and Mental Retardation Authority of Harris County, and the Harris County Children's Assessment Center, provided the staffing to create an on-site psychiatric emergency and clinic care facility.

Psychiatric evaluations included psychological and social assessments, and heavy emphasis was placed on counseling to prevent the development of major depression and posttraumatic stress disorders. Acutely suicidal, aggressive, and agitated patients were treated on site whenever possible to avoid transfers to already fully occupied psychiatric hospitals. In all, only 2% of treated psychiatric patients required transport to more acute settings. Many patients lost or left behind their medications during evacuation and simply required refills. Substance abuse, intoxication, and withdrawal were treated, including transportation to alcohol and drug detoxification and rehabilitation facilities and local methadone clinics.

More than 500 psychiatric patients were registered and treated at the Katrina Clinic[2]; however, the number served is thought to exceed 900 patients. This discrepancy is most likely

due to the absence of an early formal registration and medical record documentation protocol. The agitated state of many of these patients made their registration at the very busy and congested Katrina Clinic almost impossible and required the development of a different triage approach, usually inside the shelters. Mental health workers were required to actively search for patients inside the shelters and initiate treatment because these patients were usually unwilling or unable to seek help. Many patients were found during the night, when their presentation became more obvious because of the surrounding sleeping population.

CONCLUSIONS

The Katrina evacuees arriving in Houston/Harris County from the devastated areas of the Gulf Coast presented a formidable problem for the regions' medical, emergency, and public health systems, especially considering the lack of information available about evacuees' medical conditions. The precipitous arrival of thousands of evacuees—at one point, 30 to 40 buses with 50 to 60 evacuees per bus awaited triage by medical personnel and entry into Astrodome/Reliant Center—overwhelmed the Red Cross's initial intake system. This made registration and tracking of evacuees during their stay and eventual exit to their final destinations difficult and later affected the ability of Astrodome/Reliant Center personnel to reliably quantify demographic data.

More accurate patient information was obtained, however, for those seeking care in the Astrodome/Reliant Center clinics. Astrodome/Reliant Center Medical Branch Operations were able to partner with community providers to staff the rapidly deployed disaster response clinics with community-based health clinic medical professionals and emergency response staff. Triage personnel successfully identified evacuees with clinical conditions warranting transport to area hospitals. This initial and later medical triage was coordinated within the Medical Branch by Southeast Texas Trauma Regional Advisory Council's constant communication with the Catastrophic Medical Operations Center. Regional medical coordination through the Catastrophic Medical Operations Center was imperative because of the simultaneous evacuee and triage operations at the George R. Brown Convention Center and Ellington Field airport.

Use of Preexisting Community Relationships

The creation of an Astrodome/Reliant Center–like shelter, the Katrina Clinic, and a medical triage site at bus disembarkation areas can be rapidly deployed when massive resources are mobilized and the proper individuals receive the necessary authority and responsibility to provide command and control. However, unless a preexisting local medical infrastructure can assume command and control of large-scale evacuee medical care, such a response may not be sustainable. The use of the preexisting relationships and expertise of the Harris County Public Health and Environmental Services and Harris County Hospital District Community Health Program, staffed by Baylor College of Medicine providers, allowed a sustained response for the 3 weeks of the Astrodome/Reliant Center's operations. The Regional Hospital Preparedness Council's Catastrophic Medical Operations Center coordinated the movement of evacuees in need of higher-level medical care into regional hospitals, avoiding undue burden on any one health care facility. Later, when federal and state medical assets arrived, these personnel successfully blended into the local command and control structure, already in place.

Recommendation. If possible, establish and nurture preexisting medical provider relationships for disaster response because local community health care agencies often assume care of displaced persons during disasters. We also recommend developing a Catastrophic Medical Operations Center to coordinate and promote situational awareness of acute health care facility capacity and capability. To maintain continuity of care after the initial disaster response by national and state emergency responders, external support agencies, such as Federal Emergency Management Agency, Disaster Medical Assistance Team, and the military, should align their medical support with local community health care resources.

Use of Large Sheltering Facilities

The advantages of using a collection of buildings such as the Astrodome/Reliant Center to rapidly integrate 27,000 evacuees were as follows:

1. Ease in securing a large complex rather than individual buildings
2. Availability of logistic support and inventory, making all amenities and resources available on site
3. Close proximity to the Texas Medical Center and other hospitals within Trauma Service Area-Q

A stadium or convention center can accommodate the arrival of thousands of people per hour during an emergency. The challenge is to sustain a population in these structures during weeks to possibly months in the event of a catastrophic disaster. The main Katrina shelter, the Astrodome, which was not scheduled for any events during the Katrina operations, was made available on short notice; however, it presented many medical and logistic problems because of the multiple floors used to accommodate evacuees.

Recommendation. In place of stadiums or arenas, we recommend the use of large flat buildings for evacuee shelters, such as the Reliant Center or the George R. Brown Convention Center in Houston/Harris County. If stadiums or arenas are to be used for this purpose, more consideration should be given to controlling access to various levels in which evacuees may be sheltered.

Definition of Roles/Responsibilities and Controlling Access for Personnel

Roles and responsibilities of all personnel allowed in the shelter and clinic areas should be clearly defined. Media and celebrity access to sheltered evacuees should be restricted. The

Astrodome/Reliant Center shelters served as temporary "bedrooms" for thousands of homeless traumatized evacuees. In some circumstances, reporters, photographers, television staff, and celebrities had relatively unrestricted access to evacuees. This situation caused discomfort to evacuees, some of whom were observed hiding under their cots to avoid the media. Although the Astrodome/Reliant Center's Unified Area Command personnel were cognizant of privacy issues, they had difficulty maintaining control over the media.

Recommendation. Unified Area Command (or an alternate command and control structure) should define the rules for nonmedical access into living and medical facilities. In particular, a code of conduct should be established for reporters, photographers, television crews, and celebrities. Law enforcement should strictly monitor and control access, as determined by the Unified Area Command.

Recommendation. We recommend that shelter medical treatment sites establish and maintain adequate security and privacy during treatment encounters.

Nontraumatic Nature of Medical Care Conditions

Table 1 shows the primary medical diagnoses for the evacuees (respiratory and gastrointestinal conditions), with the remaining clinical diagnoses distributed across all medical diagnostic groups, an important observation for future nontraumatic disaster management strategies. Data from the Katrina experience may be used to develop patient care models based on the flow of patients with a broad spectrum of medical complaints. Medical and logistic data collection during the Houston Katrina response was possible because of the existing community health system's electronic patient care record into the Astrodome/Reliant Center, Catastrophic Medical Operations Center's patient tracking, system, and epidemiologic surveillance that was set up by the "cot-to-cot" monitoring of symptoms at the medical care sites and the shelters. These data were used in "real time" by the Catastrophic Medical Operations Center to track patient medical conditions and outcomes for the purposes of better medical logistics planning, identification of emerging disease trends, and informing the local community health service providers.

Recommendation. To respond to the dynamically changing patient demographics, real-time surveillance systems based on a reliable entry/exit registration system should be established during large-scale sheltering of evacuees. Summaries of such data may be helpful once the response efforts are completed to better understand the nature of the response. Additionally, a regional patient tracking system providing multiple input sites, a coordinating entity for placement of patients, and a receiving facility notification system are recommended to track data trends, provide overarching situational awareness, and track or locate patients.

Populations With Medical Special Needs

During the first week of Astrodome/Reliant Center operations, medical personnel observed elderly (oftentimes nursing home patients) and children (oftentimes lost and scared) among the general shelter population. Astrodome/Reliant Center medical staff immediately formed special outreach teams to locate evacuees in need of specialized care, such as:

1. sick evacuees who could not get to the shelter treatment areas;
2. evacuees whose medical conditions had deteriorated since bus disembarkation;
3. the disabled who could not walk to triage;
4. the visually impaired who, without their glasses left in Louisiana, could not read signs;
5. the hearing impaired who could not hear announcements;
6. the cognitively impaired who could not communicate their needs;
7. the elderly who were not oriented to time, place, and possibly person; and
8. children without a guardian.

Once identified, these patients were transferred to the appropriate authority (Adult or Child Protective Services) or relocated to a secure space adjoining the shelter treatment sites, where more intensive observation and intervention could be provided. For the elderly, a single point of contact was established with Adult Protective Services to authorize all patient transfers out of the Astrodome/Reliant Center. This system was implemented to stop unauthorized nursing homes and assisted care facilities from removing non–compos mentis patients without consent of the shelter medical teams. The expansion of the definition of "special needs" patients and the flexibility/creativity of caring for these persons was quickly required during the Astrodome/Reliant Center response. For example, the diabetic patient without (1) insulin, needles, and syringes (or ways to dispose of the latter); (2) the ability to monitor blood glucose levels; (3) awareness of previous dosing; and (4) refrigeration for their insulin quickly became medical special needs patients.

Recommendation. Patients with medical special needs should be triaged before shelter placement. Child and Adult Protective Services should be represented at disembarkation sites. Fellow evacuees should be reminded to alert local support personnel (Red Cross, law enforcement, volunteers, etc) and medical teams about patients with special needs. The definition of what composes a patient with medical special needs may need to be expanded.

Patient/Evacuee Tracking System

After bus disembarkation, many evacuees would not enter the shelters for fear of missing or losing other arriving family members. Once inside the shelters, evacuees were observed frantically searching among thousands of cots for family and friends. If these attempts were unsuccessful, evacuees had no other means to determine whether family members had survived to relocate to another area. In some cases, evacuees from Arkansas were transported by the military to the Astrodome/Reliant Center for family reunification after Red Cross

identification and connection. Several agitated and distraught evacuees presented to the Katrina Clinic asking for help in locating their family members. Patients with gastrointestinal disease were sequestered in an isolation unit adjacent to the Katrina Clinic; these patient transfers were undocumented by Katrina Clinic triage staff, who feared contaminating patients in the waiting areas. In many instances, these transfers occurred without notification to other family members. Real-time patient tracking may shorten the length of time spent by evacuees looking for lost relatives or friends.

Recommendation. A single regional individual tracking system among all disaster facilities should be quickly activated. This system should be available to regional (eg, Catastrophic Medical Operations Center) treatment areas, shelter managers, emergency management, medical examiner offices, EMS, and hospitals from disembarkation into triage sites and shelters. This system should also have the capability to track individuals across jurisdictional boundaries and include patients, evacuees, pets, etc. Registration on intake and "checkout" on exit should be emphasized.

FORWARD WORK

To understand the effect of Katrina on Houston/Harris County outside of the Astrodome/Reliant Center experience, further data should be gathered and analyzed. At the time of this article's preparation, inpatient and emergency data were available only from the Catastrophic Medical Operations Center and Harris County Hospital District. However, 93 other medical facilities within Trauma Service Area-Q accepted patients from the Astrodome/Reliant Center, and some of the 250,000 migrating before the landfall of Katrina also required hospitalization in these facilities. With at least 100,000 displaced still living in Houston/Harris County, it is important that these data be included in a future work. The integration of the Astrodome/Reliant Center data with all Trauma Service Area-Q Katrina-related patient encounter data will assist a regional forecast of the near-term and long-term influences of a disaster such as Katrina. Other agencies—the Red Cross and CVS pharmacy—may have important data to help predict the logistics required in other types of encounters.

SUMMARY

Harris County, the City of Houston, and Trauma Service Area-Q successfully provided evacuee medical care and shelter for as many as 27,000 Katrina evacuees at Astrodome/Reliant Center during the 3-week Katrina response. The pre-Katrina creation of the Catastrophic Medical Operations Center, based on the experience obtained from previous hurricanes and Tropical Storm Allison, allowed regional planners to identify additional medical surge capacity within Trauma Service Area-Q. The rapidly created Astrodome/Reliant Center shelter facilities triaged, treated, registered, fed, cleaned, and clothed evacuees at a rate of about one every 15 seconds for the first 3 days. Many of these evacuees have since permanently relocated to Harris County.

One author who supported the bus disembarkation triage site was overheard saying to arriving evacuees, "We are very sorry this happened to you. It is really going to get better. We promise!" The Houston Katrina disaster response team did their best to keep that promise. With proper planning, this outcome can be achieved by any other city, county, region, or state providing care and shelter to evacuees who have experienced a similar disaster.

As medical providers during this large-scale response effort, the authors wish to thank the 60,000 volunteers, the various law enforcement agencies, the military, the regional medical facilities inside Trauma Service Area-Q, the Regional Hospital Preparedness Council, the Southeast Texas Trauma Regional Advisory Council, the Houston Fire Department, the City of Houston, Harris County (including Harris County Public Health and Environmental Services, Harris County Hospital District, and Mental Health and Mental Retardation Authority, among others), Baylor College of Medicine's Department of Family and Community Medicine, and the numerous other federal, state, regional, and local partners for helping to sustain the Astrodome/Reliant Center response. Many of the authors soon became evacuees themselves when then–category 5 Hurricane Rita was poised to strike Houston/Harris County in October 2005. Eventually, the authors were fortunate to return to their homes with their families intact. Nonetheless, the authors came to appreciate the experience of the Katrina evacuees, many of whom lost everything.

Supervising editor: Kathy J. Rinnert, MD, MPH

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article that might create any potential conflict of interest. The authors have stated that no such relationships exist. See the Manuscript Submission Agreement in this issue for examples of specific conflicts covered by this statement.

Publication dates: Received for publication March 27, 2008. Revision received May 28, 2008. Accepted for publication September 25, 2008. Available online January 10, 2009.

Reprints not available from the authors.

Address for correspondence: Douglas R. Hamilton, MD, PhD, MSc Eng, Department of Family and Community Medicine, Baylor College of Medicine, 3701 Kirby, Suite 600, Houston, TX 77098; 713-477-6851, fax 713-798-3644; E-mail douglash@bcm.tcm.edu.

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