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### Hurricane Evacuations of the University of Texas Medical Branch at Galveston

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#### 1. Introduction

Hurricanes develop in the trade wind zone over sea, when the water temperature rises above 79.7 °F. A temperature difference between sea level and high heights might lead into a tropical whirlwind. A hurricane develops air speeds of more than 75 mph (rotation speed) according to the wind force of 12 Beaufort. The moving speed of the swirl is only 9.32 - 18.64 mph. The circumference of the storm can be hundreds of square miles. Hurricanes can stay active for weeks and devastate areas of thousands of square miles. The yearly time of origin is limited from May to December (Kim et al., 2009).

The City of Galveston is settled in the greater Houston area, about 50 miles southeast of Houston, Texas on an elongate offshore island in the Gulf of Mexico. This island is the south boundary of the Galveston Bay and the Houston Ship Channel. In September 1900 a hurricane devastated Galveston, destroyed much of the city and claimed the lives of approximately 6,000 to 8,000 people. At that time the average elevation of the island was only slightly above sea level. After the storm Galveston was rebuilt at a raised level and further protected from the sea by a concrete seawall that rises 17 feet above mean low tide (Alperin, 1977).

The University of Texas Medical Branch (UTMB) was founded in the year of 1891. Today UTMB consists of four schools (Medicine, Nursing, Health Professions and Graduate School), seven hospitals on campus, as well as three institutes and a network of more than 100 campus and community based clinics. Although not owned or operated by UTMB, the campus is also home to the Shirner's Burn Hospital, which is staffed by UTMB faculty and researchers. The number of employees is approximately 13,000, plus 2,900 students. Furthermore, the Galveston National Laboratory, which is one of two biodefense laboratories of the US government is located on campus. UTMB is also the site of a regional Level-1 trauma center and the University's annual budget is approximately \$1.6 billion (Sexton et al., 2007).

In September 2005 UTMB was threatened by hurricane Rita. Abandoning its historic practice of sheltering patients and staff in-place or clearing the hospital of all but the sickest patients, UTMB rapidly organized and conducted the first total evacuation in its 114-year history. Threatened for the first time by the possibility of a category five hurricane with a 20-feet storm surge that carried the potential to inundate the island. UTMB's leadership was determined to avoid the disastrous effect of hurricane Katrina seen in New Orleans only weeks earlier. Three days before landfall the incident command center which functioned as

the decision-making and communication hub throughout the storm, was activated as specified in the UTMB emergency operations plan. The primary spokesperson and sole person responsible for the evacuation, was the Incident Commander who lead UTMB through this challenging event. However, the evacuation went smoothly and was successful. Hurricane Rita caused only minor damage on Galveston Island and the UTMB campus. Therefore, the clinical and scientific staff could resume work less than one week after the landfall of Rita. Just three years later in September 2008, UTMB was again threatened by hurricane Ike and again had to be evacuated (Maybauer et al., 2009). In the following we will report how this was accomplished, what impact Ike had on Galveston Island and UTMB, and what lessons were learned from both hurricane evacuations.

#### 2. The hurricane lke evacuation

UTMB emergency management officials and executive leadership began tracking hurricane Ike late in the week of September 1st, and participating in the Texas Division of Emergency Management State Operations Center conference calls with the National Weather Service (NWS) on Sunday September 7th. Predicted paths varied from the lower Rio Grande Valley to the Florida panhandle early on, but it was assumed that a Texas landfall was likely. By Tuesday it was felt that the storm track would make landfall at Corpus Christi, Texas and concern over a Galveston landfall was reduced somewhat. On Wednesday new NWS data indicated a likely upper Texas Coast strike and UTMB leadership were re-engaged in preparations for this storm. It was determined that a full-scale patient evacuation would be necessary and assessments were quickly conducted to position transportation assets to arrive in Galveston on Thursday September 11th. By late Wednesday the UTMB leadership was committed to an evacuation decision early Thursday morning, and this was in fact the case, given the overnight weather information.

UTMB evacuated 469 patients from the inpatient towers, correctional hospital and behavioral health facility. Of these, some 80 were neonates including Infant Special Care/Intensive Care level 2 and level 3 babies. Patients were transported to facilities in Austin, San Antonio and Dallas-Fort Worth metropolitan areas.

According to the special situation of the City of Galveston, a hindering factor for an extrahospital ground transport evacuation is the 2 mile long causeway leading to Galveston County. Ambulances can only pass this bridge safely if wind-speeds are below 40 mph. Such wind speeds may occur as early as 12 hours before the hurricane makes landfall. As such, planning efforts need to assure that an evacuation should be finished no later than this time point of 12 hours. This specific time was calculated for Friday, September 12th 2008 at 12:00 noon. The evacuation plan of UTMB envisions for such kind of storm tide events, and a countdown of 120 hours (5 days) begins and a "countdown clock" from H-120 hours tracks significant events against the time remaining before tropical storm force winds arrive. The phase of 120 to 73 hours pre arrival of the hurricane estimates a normal hospital duty roster and two daily conferences in the Emergency Operations Center, under the leadership of the Incident Commander. A final decision for an evacuation must be made by 72 hours pre arrival, in order to request evacuation assets in an adequate number and with appropriate staff and equipment, before this time point. Simultaneously, elective admissions and transfers of patients to UTMB hospitals were stopped. Locally arriving patients received only ambulatory or stabilizing treatment in the Emergency Department (ED) and were

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discharged or transferred to other hospitals. Four hundred, sixty-nine (469) patients were evacuated during Thursday September 11<sup>th</sup> 2008, during the period of 36 to 24 hours before the estimated arrival of sustained 40 mile per hour winds (H-0). All mobile patients and those without need for monitoring were discharged directly and picked up by family members. Eighty-two patients were transported by coach. One hundred, forty-three (143) ambulances were sent to Galveston from a staging area in San Antonio, Texas, some 225 miles away. Forty-eight patients were transferred by ambulance to the nearest airports. Following these shuttle-transports all available 143 ambulances transported patients to the above mentioned hospitals. An additional 23 patients would be picked up by helicopters, directly from the landing deck of the UTMB Emergency Room. One hundred and two correctional patients were transferred from the hospital operated jointly by UTMB and the Texas Department of Criminal Justice. The patient evacuation was completed within approximately 11 hours with the last patient arriving in Austin just before midnight Thursday night.

UTMB had released students on Wednesday, and non-essential personnel on Thursday, as well as essential personnel who were not required to ride-out the storm as evacuations were completed. The UTMB Emergency Operations Center was fully activated on Thursday morning to support the patient evacuation and finalize planning for the hurricane. Contact was established with the State Operations Center/Department of State Health Services Liaison, to keep them apprised of UTMB's status, and with the Regional Catastrophic Medical Operations Center operating at the City of Houston Emergency Operations Center.

Tropical storm force winds were recorded beginning in the early evening hours of Friday, and sustained winds of 70+ miles per hour by 22:00. Storm surge and wind driven rain resulted in flooding of lower located areas of the campus by 17:00 and flooding was reported in the McCullough Building basement. Power outages and transfers to generators were reported sporadically beginning at 19:00. Water was first noticed in the lobby of John Sealy Tower by 23:00, and the first floor was cordoned off at the stairwells. At 21:45 John Sealy Annex transferred to generator power and at 23:00 the command center was relocated to the 5th floor of John Sealy Tower. At this time the tower had lost primary power and was being supported by emergency generators. By 01:45, shortly before the eye of the hurricane was over land, water was reported to be over two feet deep in the tower lobby. By 09:30 on Saturday morning the winds had diminished, and water had begun to recede. At this time a roster check revealed all personnel were accounted for and safe.

By early Saturday afternoon it was safe to venture outside and damage assessments were begun. An all-staff meeting was called for 15:00 and reports were received from police, facilities, environmental health and command personnel. Early damage assessments indicated that the flooding and interruption of essential services (domestic water, sewer and power) would mean healthcare, research and educational activities would be interrupted for an undetermined period of time. UTMB entered a "preserve and protect" mode and began the process of ordering reserve generators, pumps, chillers and electrical equipment to initiate the recovery phase.

Recovery was expected to continue for several months.

#### **3. Hurricane lke information**

Hurricane Ike was a storm that had significant impact over a wide area of the Caribbean and the US. While categorized as a Category 2 storm when it made landfall in Galveston, its size, timing, duration and the associated coastal surge had the impact of a much greater

storm. Hurricane Ike formed September 1 st, 2008 and dissipated on September 16th, 2008. Highest sustained winds were reported to be 145 mph prior to landfall at Galveston. The eye of Ike passed over UTMB in the early morning hours of Saturday September 13th, at which time the severe flooding across virtually all of the campus was recognized. While wind speeds were diminished to Category 2 force at landfall in Galveston, the size of the storm stretched those winds over a 510 miles area, much larger than the size typically associated with a Category 2 storm. The result was a significant storm surge and a much longer period of wind and surge impact as compared to other Category 2 storms that have hit the Texas Coast. Just before landfall and at landfall, Ike's winds ranged from 92-110 mph based on National Oceanic and Atmospheric Administration/NWS Galveston's report. The eye of the storm made landfall in Galveston at approximately 02:10, about 2 hours before the morning high tide. The combination of surge and tide resulted in a storm surge typically associated with a Category 4 hurricane. Ongoing studies on storm surge, predict that the maximum surge expected from a hurricane at Galveston is 19 feet at the shoreline. While official reports show a 7 feet surge at the east end of Galveston Island. The back wash wave resulting from release of the surge being pushed up into Galveston Bay as the eye of the storm passed over, resulted in a wave of water from the north pushed by the shifting winds that rose in excess of 14 feet in certain areas of the UTMB campus. The variation in high water elevations experienced, are thought to be due to the characteristics of the path traveled and the strong wind gusts. In some cases the movement of the water into a building wall was accelerated by strong winds pushing the water to elevations higher than the general surge.

#### 4. Emergency preparedness, response and recovery preparation

Preparation for the storm started as the storm approached the Gulf of Mexico. Standard preparations start at the beginning of each hurricane season and the Emergency Standard Operating Procedures served the campus well. Hurricanes Dolly, Edouard and Gustav earlier in the year each served to help prepare for Ike. The situational awareness was at a very high level. There were lessons learned in each previous storm that served to prevent even greater impacts to the campus facilities and helped prepare staff for this event. For Ike, the decision to evacuate patients and non-essential personnel, students and staff came Thursday (36hrs) before the storm. The evacuation went smoothly. Other preparations included ensuring the supply stock was full, preparation of the command center, cleaning up and tying down loose equipment, and hardening certain areas for wind. Reserve supplies of diesel fuel, food, potable water and linens were ordered and delivered in the days before the storm. A mobile kitchen facility was reserved on Wednesday before the storm, and was delivered and installed during the week after Ike. This kitchen served meals for the university staff and recovery workers immediately after the storm, and continued in operation for many months due to the loss of the main kitchen and dining area on the first floor of the hospital complex.

#### 5. Response

The initial storm impact to the campus was the rising water due to the storm surge. Water started accumulating in low located areas Friday morning and by afternoon had completely covered the plaza in front of the Ashbel Smith Building. As afternoon came, the winds picked up and started pushing water up against various buildings. A fire broke out at the Galveston Yacht Basin's dry boat storage facility Friday afternoon. This building was located several

hundred yards north of the UTMB campus. Due to the high water in the area, the fire department was unable to access the fire and extinguish it. The smoke from the fire was blown into the Emergency Department causing the ED to relocate their operations to the Waverley Smith Pavilion Hospital on the eastern edge of the campus. The move was a pre-planned action following the campus contingency plan and went smoothly. This location served as the primary entrance point for EMS-transported patients throughout Sunday and into Monday after the storm. Some lessons were learned in using the Waverley Smith Pavilion as the interim ED such as understanding access issues through corridors that were not designed for patient movement, but the operations were maintained without significant impact. As the winds increased and the water surge levels rose, normal power was lost just before 22:00 Friday night. The emergency generators came on to provide power to the areas designed to receive emergency power. Other areas remained dark. The loss of normal power was three hours before the eye of the storm reached the island, evidence of the size of the storm. The overall period of extreme wind and rain lasted over eight hours. The UTMB Incident Command Center operated throughout the storm, despite loss of communications for a period of time and relocation to a previously designated alternate location on the 5th floor of John Sealy Towers. The loss of communications was due to the flooding of the communication lines splicing (in the low lying junction boxes), the loss of cellular antennas and of the short wave radio boosters. The first communications to come back was cellular telephones aided by the arrival on Sunday of an AT&T mobile wireless cell system.

The storm surge was the critical factor in hurricane Ike. Water entered the ground floor, crawl spaces and basements of most buildings. The most substantial water incursion was into the McCullough Building where the linear accelerators were flooded. The wind damage was minimal with some windows lost and some roof damage. Mud and debris covered all areas that had been underwater. In a prior flood assessment it was noted that the highest flood water level recorded was at elevation 14 feet. The impact from the storm resulted in high water ranging from around 8 feet to 14 feet across the campus. The back wash from Galveston Bay as the eye of the storm passed pushed water up in certain areas breaching the entry points to the buildings.

The catastrophic damages to Galveston Island resulted in loss of all municipal and franchise utility services. Normal electrical power was lost during the storm and damages to equipment and campus systems hindered the restoration of power until the buildings were capable of receiving electricity. Normal power started to come back a week after the storm and was not completely restored until October 6<sup>th</sup>. All but three generators continued to operate in certain buildings while the equipment and the systems were being restored. Natural gas to the island was shut off for fear of fire and explosions after the storm. The municipal water system was lost for almost 2 weeks due to the destruction of pumps and generators at the main water plant, affecting fire protection, use of toilets and municipal drinking water. The municipal water system was lost as well, providing no treatment for sewage until the city's treatment facilities could be restored. Loss of municipal water also meant that air conditioning chilled water systems that relied on city-supplied water for cooling tower make up could not operate. Debris clogged storm drains. The restoration of the systems just to start to serve the campus took over three weeks.

Galveston Island was closed to all traffic except emergency first responder personnel for several days and residents were only allowed to return to inspect property and leave the island before the 06:00 pm curfew that lasted for over two weeks. As a result, essential

UTMB personnel were instructed to remain evacuated, and Disaster Medical Assistance Teams (DMAT) were requested via the State Operations Center. DMAT personnel from more than four states arrived within 48 hours of landfall and provided medical care in the UTMB Emergency Department for over two weeks. At that time UTMB personnel were able to resume emergency treatment, but no patient admissions were possible due to lack of inpatient facilities. All patients were treated and released or stabilized and transported to more appropriate facilities. It was expected that local EMS continued to divert patients to other facilities for life threatening, or complicated conditions for at least 90 days after Ike. UTMB reopened for admissions – limited to Obstetrics and Gynecology patients – 30 days after the hurricane, and admissions were expanded in a phased fashion, as staffing and critical services would allow. By mid-January 2009 over 200 beds were in operation and by the end of May, 370 inpatient beds were staffed on a daily basis.

#### 6. Damages at UTMB due to hurricane Ike

- Loss of function for all offices, support areas, clinics, and mechanical spaces on the first floor of approximately 80 buildings, including (but not limited to):
- 3 Emergency Generators and automated switching equipment
- Hospital Pharmacy Robotics System
- ALL elevators (132)
- All Chilled Air Supply
- All Domestic Water
- All Local Power
- Sterile Processing
- Day Care Center
- Outpatient Clinics
- Materials Management / Central Supply
- Hospital Admitting Office
- Warehouse (surplus equipment and storage)
- Blood Bank (Donor Center and Cross match Lab)
- Food Services
  - Main Kitchen, Retail Food Service, Cafeteria
  - Steam due to flooded pits and link seal breach.
    - Critical to Animal Cage washing
    - Sterilization
    - Hot water

#### Condensate, domestic water, sump and other pumps due to flooded conditions

- Medical Gas Vacuum Pumps
- Student Housing
- Main Hospital Supply, Laundry/Linen distribution center
- Linear Accelerators
- Various Research and Clinical Laboratory Analyzers susceptible to high humidity
- Hospital Clinical Equipment Services
- Research Fabrication and Machine Shop
- ALL physical plant / maintenance tools, spare parts, etc.
- 37 Motor Vehicles, including 2 Bloodmobile and 1 Mobile Mammography Coaches

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- UTMB Chapel
- UTMB Bookstore, Gift Shop and 2 Starbucks kiosks.

#### 7. Impact and long term recovery

Hurricane Ike's biggest impact was to UTMB's critical core buildings and operations. The buildings on the campus are categorized by the critical nature of each buildings function. Those buildings that must remain operational at all times are addressed differently than those buildings that can be evacuated without significant impact to the operations of the campus.

The impact on these buildings was assessed as follows:

- Over 1 million square feet of building space flooded to depths ranging from 6 inches to 6 feet
- Of the 36 critical Buildings in the Research and Healthcare Complex Core, 32 (89%) buildings were damaged due to flooding.
- Of the critical core Healthcare Buildings only, 10 out of 11 (91%) buildings sustained flood damage
- Of the Academic and Primary Support buildings 20 of a total 25 buildings sustained flood damage

#### 8. Damage estimate

The damage to the UTMB campus was significant. The preliminarily estimated cost to UTMB was \$710 million, and is likely to grow to over \$1 billion, including but not limited to costs for the following:

- Patient evacuation
- Student relocation
- Building damage
- Campus cleanup,
- Infrastructure and equipment repair
- Business interruption
- Research equipment
- Reconstruction to pre-hurricane conditions
- Mitigation against future flood events (water resistant materials and finishes)

Damage estimates elsewhere in the impacted areas were substantial. By November 2009 over 780,000 damage claims had been received by the Texas Department of Insurance with a gross loss value of \$10.64 billion, and net (after insurance payments) of nearly \$5 billion. In Galveston County gross damages were estimated at \$2.3 billion and over \$591 million after insurance payment – NOT including damages at UTMB (Texas House of Representatives Interim Report)

#### 9. Discussion and conclusions

Disaster preparedness plans in hospitals are indispensable for a successful completion of a hospital evacuation. Disasters like the flooding of 2002 in the Oder-Elbe-region in Germany,

the South-East Asia tsunami in 2004, or the flooding of New Orleans, Louisiana, USA during hurricane Katrina in 2005, and Galveston, Texas during hurricane Ike in 2008 has let us become aware that flood catastrophes are not only documented far away from us, but they can happen everywhere and could also occur in our neighborhood. Catastrophes do not follow any rules and are barely predictable according to time and location. To become ready for catastrophic cases, it is relevant to develop localized structures, disaster plans and to establish drills. The following functional sections should be established: incident commander, incident planning, logistics, administration, communication (internal, with committees and media), and security (Born et al., 2007a, 2007b; Zane & Prestipino, 2004). At UTMB in Galveston, valuable lessons have been learned from the sequential evacuation

of the university hospital. An adequate disaster preparedness plan and logistics were crucial for the success. The lessons learned from both experiences included especially the following:

- 1. Appointment of an Incident Commander. This person must be given sole authority for decision making. He or she should also have clinical experience, and occupy an executive leadership position (Sexton et al., 2007).
- 2. Having an emergency operations center or Incident Command center utilizing National Incident Management System (NIMS) principles (DHS, 2008) to support the incident commander is crucial for success. The center helps to communicate decisions and developments internally and externally, and serves as advisor for the incident commander. It is the responsibility of this leadership to not delay the decision to evacuate or worry about anyone second guessing the decision. The sooner an evacuation may be started, the higher the likelihood that the evacuation will proceed accordingly to the emergency plans. The Incident Command center has to keep track of evacuated patients and on-site personnel, to utilize expert clinical staff (MDs and RNs) to coordinate loading of ambulances and helicopters for patient transfer, or to reassign staff as necessary to care for transferred patients (Zane & Prestipino, 2004).
- 3. Having reliable in-house communication system not dependent on telephone lines or electricity; During hurricane Rita it was discovered that some of the communication devices such as walkie-talkies or cell-phones were either outdated or did not work in too many "dead" areas of the campus. These issues had been addressed and could be solved during drills before hurricane Ike approached Galveston (Sexton et al., 2007).
- 4. Having a reliable telephone system for contacting outside facilities is very helpful to keep track on patients, because ambulances may become stuck in traffic on evacuation routes or have to take alternative routes to make their way to the admitting hospital; or even reroute patients to another health care center. The lack of this information may hinder the ability to communicate effectively with family members (Maybauer et al., 2009).
- 5. Maintaining a paper record of all patients, and patient transfers as well as all other business transactions; The data of electronic medical records may not be accessed in a different hospital because of software or system differences (Sexton et al., 2007).
- 6. Every healthcare facility hospitals, urgent care facilities, ambulatory care facilities, long-term care and skilled nursing facilities etc. should develop evacuation plans beyond the typical fire evacuation plan, that anticipate interruptions in services. Any internal or external cause should be anticipated including power, water or medical gas failures, wind and/or rain damage, loss of critical internal services such as pharmacy, food preparation and/or distribution, non-functional operating rooms, and any other

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vulnerability identified for the facility or location. The regular testing of these plans is an essential component of preparedness and ultimately successful execution of the plan. Flooding will occur in coastal areas resulting from a hurricane surge. Emergency power and temporary cooling systems are essential after the evacuation and after the storm moves inland. Emergency evacuation of a large university hospital requires extensive effort from both the hospital staff and the community. It is to remark positively that no patient inside UTMB was hurt directly by the hurricane or indirectly by the evacuation. The UTMB leadership and emergency preparedness officers continue to refine the emergency plan and related procedures on the basis of the experience during the hurricanes Rita and Ike. The authors encourage physicians, as essential members of the health care team, to become prepared to respond to disasters. A significant part of this preparation is formal training in Incident Command System and National Incident Management System concepts, which can by accessed through local emergency management officials, regional training centers or electronically from the Federal Emergency Management Agency.

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Recent Hurricane Research - Climate, Dynamics, and Societal Impacts

Edited by Prof. Anthony Lupo

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This book represents recent research on tropical cyclones and their impact, and a wide range of topics are covered. An updated global climatology is presented, including the global occurrence of tropical cyclones and the terrestrial factors that may contribute to the variability and long-term trends in their occurrence. Research also examines long term trends in tropical cyclone occurrences and intensity as related to solar activity, while other research discusses the impact climate change may have on these storms. The dynamics and structure of tropical cyclones are studied, with traditional diagnostics employed to examine these as well as more modern approaches in examining their thermodynamics. The book aptly demonstrates how new research into short-range forecasting of tropical cyclone tracks and intensities using satellite information has led to significant improvements. In looking at societal and ecological risks, and damage assessment, authors investigate the use of technology for anticipating, and later evaluating, the amount of damage that is done to human society, watersheds, and forests by land-falling storms. The economic and ecological vulnerability of coastal regions are also studied and are supported by case studies which examine the potential hazards related to the evacuation of populated areas, including medical facilities. These studies provide decision makers with a potential basis for developing improved evacuation techniques.

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