If the Worst Happens: Five Strategies for Developing and Leveraging Information Technology-Enabled Disaster Response in Healthcare

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***Abstract*—Natural disasters, such as hurricanes, tornadoes, cyclones, earthquakes, volcanic eruptions, wildfires, and floods, have a profound impact on healthcare by limiting healthcare providers' ability to effectively provide patient care in the affected areas and respond to myriad healthcare needs of the affected population. The situation can potentially be exacerbated if healthcare providers do not have effective mechanisms in place for disaster response. The response to Hurricane Katrina, a Category 3 hurricane that made landfall in August 2005 and affected several states in the southwestern U.S., was a vivid example of how the lack of effective planning and responsiveness can affect healthcare services. In this paper, based on an extensive case study, which included a rigorous examination of the Veterans Health Administration's information technology (IT) infrastructure and its response to Hurricane Katrina, we present five strategies that healthcare organizations can undertake to develop and leverage IT-enabled disaster response. These include the development of: 1) an integrated IT architecture; 2) a universal data repository; 3) web-based disaster communication and coordination; 4) an IT-enabled disaster support system; and 5) standardized and integrated IT-enabled disaster response processes. We discuss how these strategies can help healthcare providers manage continuity and offer quality healthcare during natural disasters.**

***Index Terms*—Disaster response, information technology (IT) strategy, IT architecture, natural disaster, universal data repository (UDR).**

I. Introduction

SINCE the dawn of human civilization, natural disasters, such as hurricanes, tornadoes, cyclones, earthquakes, volcanic eruptions, wildfires, and floods, have interrupted the course of civilization and in many cases put the very survival of human civilization in jeopardy. Even in recent years, catastrophic natural disasters, such as Hurricane Katrina in the U.S. in 2005, earthquake and tsunami in Japan in 2011, cyclone Nargis in Myanmar in 2004, and tsunami in Indian Ocean in 2004, have caused tens of thousands of casualties, destroyed large swaths of communities, inflicted significant long-term physical and emotional harm to the affected populations, and resulted in hundreds of billions of dollars in damages. While developing countries typically face major challenges in responding to natural disasters due to the lack of resources, the aftermath of recent disasters in countries such as the U.S. and Japan have shown that adequate responses to natural disasters are lacking even in the developed world [1], [2]. The 1973 fire at the National Personal Records Center in St. Louis is a vivid example of the lack of disaster preparedness that led to enormous loss of American veterans' records. A major challenge in the developed world is maintaining the quality of healthcare delivery in the aftermath of major natural disasters [1], [2]. For example, in the aftermath of Katrina in the U.S., the Federal Government, lawmakers, and healthcare agencies started to reexamine the entire disaster response processes related to the crisis management and delivery of healthcare [1].

Although the lives of affected people may slowly return to normalcy, the imminent threat of future disasters and questions about the effectiveness of different agencies, particularly healthcare providers in handling such disasters, is still being widely debated. According to the Federal Response Plan, the federal operational procedures to be used for disasters and emergencies to protect the lives and safety of the victims are the utmost priorities of disaster response (see www.dhs.gov for more details). Effective management of disaster responses will have substantial implications not only for the social and economic future of the affected area, but also for possible outbreaks of infectious diseases and epidemics and long-term public health.

Information technologies (ITs) have transformed our society in many ways [3]–[5]. Organizations in different economic sectors, such as healthcare, education, manufacturing, finance and banking, transportation, energy, telecommunications, retailing, and military, depend on IT capabilities to achieve successful outcomes. While the important role of IT in the healthcare sector is generally recognized (e.g., [6]), it has been a focus of much discussion and debate, particularly after Hurricane Katrina. The federal government, healthcare agencies, IT vendors, humanitarian organizations such as Red Cross, and even companies such as Wal-Mart have realized the importance of IT during disasters [7]. Many organizations have pledged increased investments in IT capabilities that will help them respond to emergencies in more effective and efficient ways. The critical role of IT in the aftermath of disaster, terrorism, and war has also been underscored in the health informatics literature [8]–[10]. We suggest

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that leveraging IT capabilities during natural disasters can help healthcare providers and other related agencies reduce the loss of lives and property, coordinate responses, report damages, track personnel movement, and immediately deploy necessary resources.

Based on an extensive case study of the Veterans Health Administration's (VHA) response during Hurricane Katrina, we propose five strategies to develop and leverage IT-enabled disaster response capabilities that can effectively respond to the crises created by a natural disaster. The VHA's effort during Hurricane Katrina has shown that an effective IT infrastructure and disaster response strategy can help reduce the loss of lives during natural disasters [11]. We have closely examined different events and organizational actions at the VHA during and after Hurricane Katrina, and use the lessons learned from the VHA to develop the strategies described in this paper. In the sections that follow, we first present the case of the VHA's IT-enabled disaster response. We then explicate the five strategies for developing and leveraging a successful IT-enabled disaster response. We conclude with a discussion of how these strategies can help healthcare providers offer high quality patient care during the time of natural disasters.

II. Case Study: Veterans Health Administration

We gathered data/information from semistructured interviews, documents, and key informants, and other publicly available sources (e.g., press releases, academic, and trade press articles). We thoroughly analyzed the data/information to identify concepts and various activities related to the VHA's disaster response and management. We verified these concepts and activities with our key informants in order to ensure the accuracy of our interpretations and analysis.

A. Background

At the time of Hurricane Katrina, the VHA operated one of the largest healthcare networks in the world with an annual budget of over $26 billion, 158 medical centers distributed in 21 regions across the country, 877 outpatient clinics, 137 nursing homes, 43 domiciliaries, 73 home care programs, 207 readjustment counseling centers, and various other facilities. It had 193,000 employees who served more than five million patients nationwide annually. The patient size increased more than 100 percent between 1995 and 2005.[1]

The VHA's healthcare system was once considered one of the worst in the U.S. It had deteriorated so badly by the early 1990s that Congress even considered disbanding it. However, in the late 1990s and early 2000s, the VHA underwent a dramatic transformation and started to be recognized as one of the best healthcare providers in the nation and a leader in almost all healthcare performance metrics. IT infrastructure and capabilities played a central role in this transformation process [12]. By the mid-2000s, the VHA was touted to have the nation's best healthcare IT infrastructure and capabilities by several media outlets, such as the Washington Post and Wall Street Journal [13]. In 2006, BusinessWeek reported that the VHA has the most advanced electronic health record (EHR) system and the most comprehensive healthcare IT architecture in the U.S. [14]. That year, the VHA also received the prestigious *Innovations in American Government Award* presented by the Ash Institute for Democratic Governance and Innovation at Harvard University's John F. Kennedy School of Government for its IT systems.

B. VHA's Response to Hurricane Katrina

It is important to note that the Department of Veterans Affairs (VA), the federal agency that supports veterans and manages the VHA, is responsible for assisting other federal agencies and the general public during emergencies, as put forth in the 1982 VA/Department of Defense Health Resources Sharing and Emergency Operation Act. Per this Act, the VA must respond to the range of national emergencies and disasters through participation in the mitigation, preparedness, response, and recovery stages of emergency management. The VHA indeed has an Office of Emergency Management that is responsible for assisting the agency in responding and managing emergencies and natural disaster throughout the four phases of the emergency management cycle: preparedness, response, recovery, and mitigation/prevention. Because of such focus and history related to emergency responses at the VHA (see [15] for a review of the VA's emergency management), it was not surprising that the VHA responded effectively to Katrina. It is important to note that over 1,833 people died in the Hurricane and subsequent floods, where the failures in New Orleans' Hurricane surge protection, considered the worst civil engineering disaster in U.S. history, prompted a lawsuit against the U.S. Army Corps of Engineers.

The VHA Medical Center in New Orleans served 39,310 patients, an average of more than 1,700 patients daily in July 2005. On August 29, 2005, within a few hours after Hurricane Katrina made landfall, the center initiated rescue and evacuation of its patients. Like other healthcare providers in the affected region, the center lost power and communications with other VHA facilities were broken. By September 2, 2005, all 192 VHA inpatients and 367 staff and family members were evacuated and relocated to other VHA medical centers. While the IT systems at the VHA Medical Center in New Orleans were shut down after August 29, 2005, all data current to that time were physically rehosted from backup tapes and integrated into the VHA's IT systems at Houston on September 2, 2005. By September 16, 2005, all patient data of the New Orleans center were available nationwide through the Houston IT systems [11].

Patient records, including prescription and pharmacy data, were accessed at over 200 care sites in 48 states and 2,300 displaced veterans with chronic medical conditions or in critical state were provided uninterrupted care within three weeks of Hurricane Katrina's landfall [11]. By the end of September 2005, 38,000 of the 39,310 patients served by the VHA Medical Center in New Orleans were accounted for and their locations

[1]The VHA is currently the largest integrated health care system in the U.S. consisting of 150 medical centers, nearly 1,400 community-based outpatient clinics, community living centers, vet centers, and domiciliaries (www.va.gov/health/aboutVHA.asp). These healthcare facilities along with more than 53,000 independent licensed healthcare practitioners provide comprehensive care to more than 8.3 million veterans each year.

were known because of the IT systems and associated disaster management processes at the VHA. In contrast, the other nonveteran evacuees of New Orleans who needed medical attention were unable to get proper care, a situation that resulted in several deaths. Due to a lack of information about these evacuees, many hospitals around the country were forced to provide medical care without proper medical records, which aggravated the conditions of many patients. The five strategies that emerge from our careful study of the VHA's activities are designed to help healthcare providers effectively develop and leverage IT infrastructure and capabilities during all forms of natural disasters.

III. Strategies for IT-Enabled Disaster Response

In this section, we present five strategies for developing and implementing IT-enabled disaster response. We draw on the various activities that the VHA performed during and in the aftermath of Hurricane Katrina to identify and elaborate these strategies. We also identify the impact of these activities on continuity and quality of care provided by the VHA.

A. Strategy 1. Develop an Integrated IT Architecture

One of the key challenges for healthcare organizations is to integrate heterogeneous IT systems developed by different vendors and located in different geographic locations. Such integration is critical for facilitating accurate, reliable, and timely access to patient records. A 2005 report by the Commission of Systemic Interoperability, appointed by the President and the leaders of the Senate, note the lack of integrated and interoperable healthcare IT systems in the U.S. [16]. The report stated that only 17% of the U.S. physicians have access to integrated and interoperable EHR systems [16]. Surveys conducted by the Healthcare Information and Management Systems Society (HIMSS) indicated that only about 20% of the hospitals have integrated and interoperable health information systems [17], [18]. Lack of interoperability among IT systems was indeed identified as a major problem in the post-Katrina response efforts. Several studies after Hurricane Katrina have illustrated that a majority of healthcare providers lack comprehensive and interoperable IT systems [19], [20]. The federal response document following Katrina clearly noted the importance of interoperability and integration in the context of healthcare technology and communications [1].

To facilitate such integration, there needs to be a common architectural platform that can provide seamless integration, standardization, and interoperability across the various IT systems. Through an integrated IT architecture, different IT systems will be able to communicate with each other using the same data format and communications standards.

Although there is a plethora of vendors and products in the healthcare IT market, a majority of these IT systems are not compatible with each other, which results in a chaotic and incomplete flow of information [21]. While each of these systems have independently improved patient record-keeping and safety, the lack of standardization and integration among the systems have made it difficult to access patient records and reduce clinical errors, particularly during the time of a disaster. During natural catastrophes, it is important that data about the displaced patients are accessed by the nearest point of care to provide immediate medical services. But even if the patients' data are available, they cannot be accessed by the point-of-care IT system due to incompatible data format and communication protocol between the IT systems.

This problem was particularly evident during Hurricane Katrina, where many hospitals had to provide medical care without being able to access patient records. An IT architecture that supports interoperability and standardization must therefore be developed to ensure that clinical records are available virtually anywhere and accessible through any health IT system. Such an IT architecture requires strong governance, risk, and compliance policies, procedures, guidelines to ensure patient records are secured and accessed only by authorized healthcare providers. In light of several high-profile IT security breaches in recent times (including the 2006 data theft incident at the VA, and the 2015 Premera and Anthem Blue Cross hacking of nearly 90 million customers), healthcare providers need to incorporate state-of-the-art security measures into their integrated IT architecture. In addition to building the necessary infrastructure for security following industry standard best practices, it is important to educate healthcare professionals regarding IT risks and security, and develop a culture conducive to a secured data and communication environment.

The VHA's experience during Katrina illustrates the benefits of having an integrated IT architecture that supports various healthcare processes through proper integration, standardization, and communication. Even though the VHA has employed many independent, geographically dispersed IT systems that support patient records, drug records, care delivery, clinical management, care management, prescription management, billing management, and several other activities, these systems are based on the same architectural platform, known as VistA (Veterans Health Information Systems and Technology Architecture). One of the key architectural features of VistA is the Health Level 7 (HL7), an American National Standards Institute (ANSI) standard messaging protocol, that specifies the set of transactions and encoding rules for secured electronic data exchange between IT systems. This protocol enables all the VistA-based IT systems to exchange healthcare information with one another using the same data exchange standards. The Department of Veterans Affairs has implemented an integrated enterprise architecture—One VA Enterprise Architecture—that would incorporate all the VA IT systems and provide seamless access to clinical and administrative data to key stakeholders—i.e., customers (e.g., patients and their family members), employees, top management, and suppliers. Fig. 1 presents the logical model for the VA's enterprise architecture.

B. Strategy 2. Develop a Universal Data Repository

An integrated IT architecture, as described in strategy 1, will be more effective if healthcare providers develop a universal data repository (UDR). A UDR is important for two key reasons. First, as patients seek medical care at several locations,

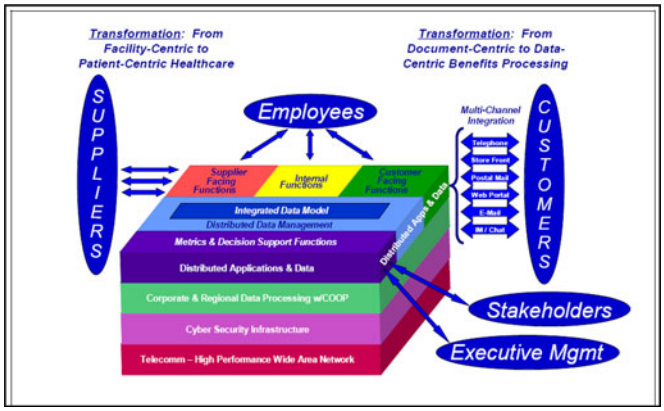

Fig. 1. Logical model for the VA enterprise architecture.
Source: One-VA Enterprise Architecture Implementation Plan: FY 2003, Department of Veterans Affairs (http: //www.oit.va.gov/).

especially during natural disasters that may lead to geographical displacement, it is not always possible to access IT systems from other providers instantaneously. A UDR stores data that are constantly updated and a particular healthcare provider can access the repository to obtain patient data. Second, a UDR will have patient data extracted from the original source. Clinicians can connect to the repository instead of the source systems, thus reducing the burden placed on the original system.

We recommend three interrelated components for a UDR: 1) patient record repository; 2) drug record repository; and 3) clinical knowledge repository. During the time of a disaster, displaced individuals often evacuate from the disaster area without their medical records. Information regarding the patients, drugs, and medical conditions—e.g., chronic medical conditions, drugs and dosage, and acute medical emergencies due to the disaster—needs to be accessed in a timely and accurate manner. A patient record repository will have this information so that preventive and precautionary measures can be assessed at the point of care during natural disasters.

A drug record repository will have information regarding known prescription drugs, such as dosage, adverse reactions, side effects, and usage directions. This information can be matched with the patients' information so that proper medication can be prescribed. During the time of a disaster, clinicians and emergency medical workers treating displaced patients can use the drug repository to understand the patients' medical history and ascertain their immediate medical needs. Similarly, the drug repository could be used to identify drug dosage and quantity, interactions and allergies, whereby pharmacists can reproduce the patients' medication and prescription records.

A clinical knowledge repository will have information about the specific illness, diseases, epidemics, conditions, procedures, drug-specific information, recommended drugs for specific medical conditions, nutrition and dietary guidelines, and pharmacies to help in clinical decision making at the point of care. During the time of disasters, the lack of clean water and sanitation can cause diseases and spread epidemics, such as typhoid and cholera. Similarly, an epidemic, such as bird flu, Ebola virus disease, Middle East Respiratory Syndrome (MERS), and

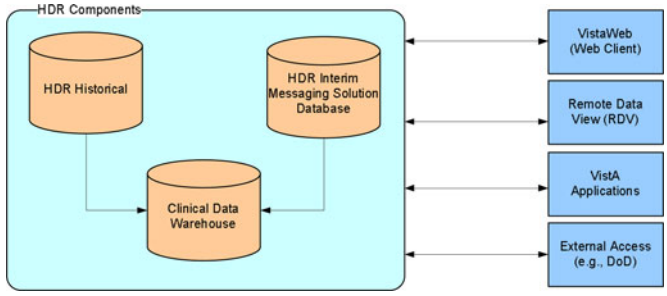

Fig. 2. VHA's HDR initiatives.

Severe Acute Respiratory Syndrome (SARS), could affect a large area in a fairly short period of time. In both cases, a clinical knowledge repository would be able to ascertain the conditions and progress of the epidemics and diseases, quarantine procedures, and medications required to treat and cure the patients as well as manage and control the spreading of these epidemics and diseases.

In the VHA, the Health Data Repository (HDR) serves as an operational clinical repository—a collection of clinical information from VHA and non-VHA sources—to be used by clinicians and other personnel to facilitate longitudinal patient-centric care. Data in the HDR are organized in a format supporting the delivery of care regardless of the physical location of a patient's clinical information. The HDR also provides additional benefits, such as providing information to support research and population analyses, facilitating patient access to data and sharing information across the VHA, and improving data quality and data security. Prior research has indeed suggested that one of the cornerstones of the VHA's disaster response was the use of patient tracking [15]. In fact, the patient tracking system in the VHA, the Computerized Patient Record System, was credited with its success in helping the agency provide patient care to thousands of displaced veterans.

Fig. 2 presents a logical model of the VHA's HDR initiative. The figure shows that data from the HDR can be accessed by VHA medical centers across the country using various IT systems (e.g., web clients and VistA applications) and by external entities (e.g., Department of Defense, DoD).

C. Strategy 3. Develop Web-Based Communication and Coordination

Advances in Internet-based healthcare solutions have rendered many opportunities for not only delivering quality healthcare through the web, but also increasing access to health information. Web-based access to medical information has been making greater inroads into the healthcare landscape than ever before. However, as mentioned earlier, a lack of a common IT architecture for integrating and connecting healthcare IT systems has been slowing the progress toward online healthcare access. A web-based healthcare solution can provide robust and timely retrieval of patient data during disasters [10]. Strategy 3 is to develop web-based disaster coordination systems that include the broad-based management and delivery of patients and clinical records to all the institutions involved in disaster relief.

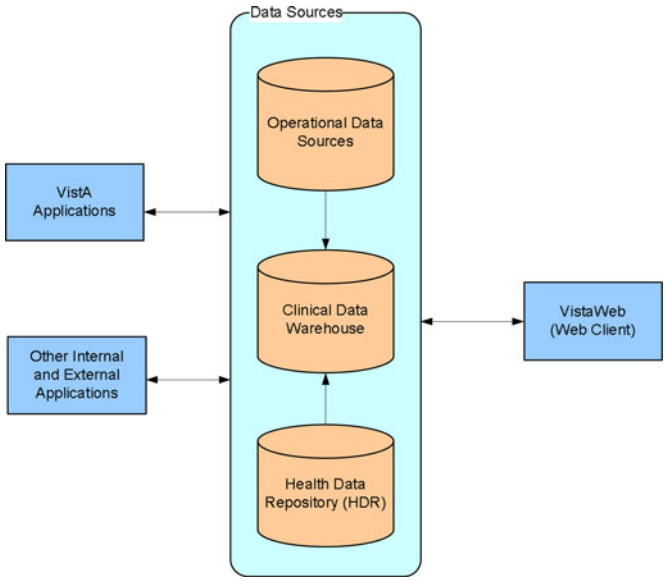

Fig. 3. VHA's VistaWeb logical architecture.

The VHA has implemented VistaWeb, a web-based remote data access system to access patients' records anywhere and anytime during a disaster. Network Health Exchange (NHE) is another system based on the VistA that provides clinicians quick and easy access to patients' information from any VHA medical facility where they have received care. NHE can access information concerning clinic visits, diagnoses, prescriptions, laboratory tests, radiology exams, and hospital admissions. It enables clinicians to request medical or pharmacy records for a patient from a single site or several sites. NHE uses predefined formats, thus requiring less input by the user and resulting in simpler, faster access to patient data. NHE also provides access to clinical information from other VHA medical centers, DoD sites, and the FDA through remote data views. Patients' records pertinent to their allergic reactions to drugs, as well as other signs and symptoms, are currently being shared across the different systems and organizations. The VHA has used VistaWeb extensively in the aftermath of Katrina to provide patient records to clinicians all over the country. Fig. 3 shows a logical model of how VistaWeb accesses data from data sources to provide accurate and timely data to the VHA facilities across the country.

D. Strategy 4. Develop an IT-Enabled Disaster Support Management System

In the aftermath of Hurricane Katrina, scores of displaced evacuees lost their lives due to lack of timely and proper medical care. The Federal Government accelerated plans for disseminating clinical information about the patients, drugs, and treatments to all the agencies and institutions involved in disaster management. Strategy 4 suggests the need to develop an IT-enabled disaster support management system. Such a system can serve to disseminate important information before, during, and after disasters so that effective medical care can be provided to displaced victims in particular. An interoperable network of clinical knowledge is necessary to accelerate the process of integrating national and regional databases of important healthcare information. Further, this system will support and deliver the current knowledge to all involved in disaster planning, management, and relief at the point of care. Finally, such a system can be extremely important in both planning for disasters and the aftermath of disasters.

By providing essential information to different stakeholders (e.g., physicians, relief workers, humanitarian agencies) at the right time, an IT-enabled disaster support system can immensely reduce the risk to public health from imminent dangers, such as communicable diseases, epidemics, bloodborne pathogens, hazardous or unsafe conditions, and other medical catastrophes. Such a system can be incorporated with the disaster management and response processes such that individuals who are part of these processes can have access to this system to make better decisions. During the time of a disaster, it is absolutely necessary to immediately alert policymakers, relief workers, hospitals, clinicians, and patients of any health hazards related to the disaster that has occurred. These systems should also be integrated with other IT systems from healthcare providers, public health agencies, relief agencies, research organizations, and the DoD systems, thereby giving disaster management personnel the information they need to react early on to medical emergencies and public health threats. The IT systems at the VHA that are based on the VistA are integrated to provide such disaster management capabilities. Table I provides examples of disaster management decision support initiatives undertaken at the VHA to help dissemination of information for better disaster preparedness.

E. Strategy 5. Develop Standardized and Integrated IT-Enabled Disaster Response Processes

Effective disaster response requires coordinated and synchronized efforts by many different individuals and functional units within the healthcare provider. These efforts constitute disaster response processes executed by healthcare providers during the time of disaster. In the aftermath of Katrina, it was evident that many healthcare providers in the affected region did not have IT-enabled effective disaster management processes in place [1], [11].

Strategy 5 deals with the standardization and integration of disaster response processes using IT capabilities and architecture (see strategy 1; [12]). It is vital for healthcare providers to develop a current understanding and thorough analysis of existing disaster response processes, and identify challenges and potential areas for improvement. In the absence of formal disaster response processes, healthcare providers need to develop effective processes and integrate them with existing clinical and administrative business processes using IT capabilities, such as a centralized data management system. However, development and integration of disaster response processes will not be sufficient for successful service delivery during natural disasters, and must therefore be in place before such emergencies happen. Healthcare providers need to standardize their disaster response processes in order to reduce variation, uncertainty, and ambiguity during process execution. This standardization requires

TABLE I
VHA DISASTER MANAGEMENT DECISION SUPPORT INITIATIVES

Clinical	Administrative
• Uncover patterns in infection control • Limit spread of epidemics and diseases due to the impact of disasters • Provide historical data regarding outbreaks of diseases during earlier disasters • Enable public health/bio surveillance, and analysis of infectious disease outbreaks • Detect patterns of nosocomial infections (device-oriented; e.g., bloodstream and urinary tract infections) and antimicrobial resistance—using lab data • Implement predictive disease management: diabetes, cardiovascular disease, and asthma • Detect patterns of adverse drug events • Reduce employees' and clinicians' exposure to bloodborne pathogens from needle sticks and sharps • Determine risk factors in a predisposition to a disease, or predict occurrence of a disease, or identify behavior risk factor trends by age group and gender • Uncover patterns in patients' admission for medical care • Identify potential targets for care and case management • Implement personalized medicine: integration of clinical genomic data • Identify availability of clinical resources such as drugs, medications, needle sticks, sharps, surgical devices, and emergency room resources • Provide first-aid at the disaster areas and en-route to evacuation centers • Identify availability of pharmacies and resource centers • Predict demand for chronic illness care, mental health, counseling, psychological services, child and women care • Provide 24/7 resources to monitor health status indicators, e.g., vitals such as weight, blood glucose, blood pressure	• Identify natural and man-made disaster prone areas • Provide disaster coordination • Forecast demand and resource requirements • Mobilize and supply relief materials • Track materials and resources • Identify places and sources of unrest and/or lawlessness (e.g., looting, violence) • Develop evacuation center occupancy management • Update patient and clinical records • Detect claims fraud • Profile disaster relief utilization • Project/direct traffic out of disaster areas and pockets of high-traffic clusters • Coordinate mobile medical centers and pharmacies during evacuation phase • Track and manage disaster coordination personnel • Evaluate safety measures at all medical and evacuation centers • Coordinate IT system support teams • Recruit personnel and volunteers in disaster relief • Identify availability of clinicians, nurses, and other healthcare professionals • Coordinate emergency 911, ambulatory care, fire and rescue services, and relief organizations • Track discharge notes, progress summary notes, all transcribed notes, lab notes, surgical notes, radiology notes, e-mail, call center triage calls, and complaints • Train personnel for disaster management

clear guidelines for the orchestration of sequential activities performed within a process, accurate and timely information, and clear guidelines on the flow of activities. IT can provide required information and guidance through the progression of activities by giving notification and maintaining audit trails of activities [22]. When integrated with appropriate IT infrastructure and capabilities, the standardized and integrated disaster response processes can ensure proper and continued healthcare services during natural disasters.

The VHA's response during Hurricane Katrina illustrates the importance of process standardization and integration with IT infrastructure and capabilities. The VHA's IT-enabled standard clinical processes and practices helped the seamless coordination of various service components, such as personnel tracking, doctors and staff tracking, patient tracking, and pharmacies' medication stocking. Further, these practices helped healthcare personnel access and manage patient, drug, clinical knowledge records, ambulatory care management, resource allocation, and tracking outbreaks of epidemics. While the city of New Orleans had difficulty for weeks in tracking and coordinating emergency personnel, such as the police and FEMA officers, local administrators, and hospital personnel, the VHA hospital was able to efficiently track and coordinate its staff to provide medical care at the highest level possible within a few hours. Standardizing disaster response processes will certainly ensure less variability, greater efficiency, and fewer errors during natural disasters. Every individual, functional unit, and external agency in this case will know the procedures and processes to follow when providing critical medical care during such catastrophes.

IV. CONCLUDING REMARKS

The strategies suggested here are not panaceas to resolve the disaster response problems faced by healthcare providers. The events and failures following Hurricane Katrina indicate that there is no easy fix for these problems [1]. There is a recognizable need, however, for long-term planning, coordination, strategic investments, and involvement of many different agencies to develop a sustainable mechanism for responding to natural disasters. The implementation of new IT and IT-enabled processes requires such coordination from stakeholders who have competing or overlapping objectives, particularly in healthcare organizations [23]. These proposed strategies will help healthcare providers understand, appreciate, and implement the role of IT in disaster response processes and encourage them to develop effective IT infrastructure and capabilities to overcome serious service interruptions during natural disasters and other emergencies.

It is possible that some healthcare organizations have already adopted and implemented some of these strategies. Federal Acts in the United States, such as the 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act and the 2010 Patient Protection and Affordable Care Act (PPACA), have incorporated provisions for offering incentives to healthcare providers for improving IT capabilities. The HITECH Act offers a set of meaningful use criteria for health IT [24] and has committed $29 billion dollars over ten years to incentivize healthcare providers and professionals to achieve these criteria [24]. Further, the Act incorporates financial penalties if eligible healthcare providers and professionals fail to meet these objectives by 2015. Although the PPACA does not include any new provisions or initiatives for IT use, it emphasizes the use of IT to improve the delivery and quality of healthcare. Recent surveys show a significant growth of IT (e.g., EHR systems) adoption and meaningful use [25]. Nonetheless, many healthcare providers are still behind in leveraging IT for clinical, operational, and disaster management processes [20], [21], [25].

Although we develop these five strategies based on the VHA's response to Hurricane Katrina in 2005, we believe that these strategies are relevant to healthcare providers for either developing or improving their IT-enabled disaster response processes. Several recent natural disasters, such as Hurricane Sandy in the Northeastern U.S. and the 2015 Nepal earthquake, underscore the importance of developing IT-enabled disaster responses to improve the overall availability, continuity, and quality of healthcare in the U.S. and the world. An integrated IT architecture can help improve the quality of healthcare services by providing seamless access to patient data, reducing errors in various clinical and business processes, and making clinical and business

processes more efficient and less costly for healthcare providers. For example, a hospital can access records (i.e., medical history, procedures performed, laboratory results) of a patient who was not treated in that hospital before and make this information available to clinicians and healthcare providers. This will help all parties make informed decisions, such as only ordering procedures that have not been previously performed on a particular patient. In the same way, other strategies, such as UDR, web-based patient record access, and standardization of processes, can also improve the quality of healthcare services in general.

While IT has certainly become an important and critical factor in the management and delivery of healthcare products and services, the one area where the IT systems have not been fully utilized is in disaster response. Large-scale natural disasters have caused huge losses of life and property in the past few years, and continue to threaten global well-being. Many healthcare providers lack the necessary infrastructure to deal with such disasters. Based on a case study of the VHA's response during Hurricane Katrina, the five strategies that we propose for developing and leveraging IT-enabled disaster response for healthcare can be of value to the Federal Government, healthcare providers, emergency management agencies, physicians, and patients for better management of healthcare during emergency response situations and events both in the U.S. and worldwide.

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Authors' photographs and biographies not available at the time of publication.