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Successful Large Hospital Evacuation With 11 350 Patients Transferred in the 2021 Zhengzhou Flood*

Zichen Zhou MPH, PhD Student[1], Yongzhong Zhang PhD[2], Jianjun Gou MMed[3], Nan Kan BCom[3], Feida Zhao Graduate Student[2], Lulu Yao Graduate Student[2] and Shike Hou MD[4]

[1]College of Management and Economy, Tianjin University, Tianjin, China; [2]Institute of Disaster and Emergency Medicine, Tianjin University, Tianjin, China; [3]The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China and [4]Institute of Disaster and Emergency Medicine, Tianjin University, Tianjin, China—Disaster Medicine of the Chinese Medical Association, Asia Pacific Division of Disaster Medicine and Public Health Preparedness

Brief Report

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Corresponding author:
Shike Hou;
Email: houshike@tju.edu.cn.

*The online version of this article has been updated since original publication. A notice detailing the change has also been published

Abstract

Objectives: This is a case report of a huge hospital evacuation with 11 350 inpatients in the 2021 Zhengzhou flood in China, using a mixed methods analysis.

Methods: The qualitative part was a content analysis of semi-structured interviews of 6 key hospital staff involved in evacuation management. The evacuation experience was reviewed according to the 4 stages of disaster management: prevention, preparation, response, and recovery.

Results: Because of unprecedented torrential rain, the flood exceeded expectations, and there was a lack of local preventive measures. In preparation, according to the alert, the evacuation was planned to reduce the workload on inpatients and to accept the surge of medical needs by the flood. In response, the prioritization of critically ill patients and large-scale collaboration of hospital staff, rescue teams, and accepting branch made it possible to successfully transfer all 11 350 inpatients. In recovery, restoring medical services and a series of activities to improve the hospital's vulnerability were carried out.

Conclusions: A hospital evacuation is one of the strategies of the business continuity plan of a hospital. For the evacuation, leadership and collaboration were important. Challenges such as prolonged roadway flooding and the infrastructure issues were needed to be addressed throughout the evacuation process.

On July 20, 2021, Zhengzhou city, Henan Province, China, experienced an extremely heavy and rare rainstorm that triggered a severe flood and caused heavy casualties and property losses throughout the city. This event was recognized by the GLIDE disaster identification system with the GLIDE ID 2021-000215. The main reason for the disaster was excessive precipitation caused by typhoon "fireworks." From 8:00 PM on July 19 to 8:00 PM on July 20, 2021, the single-day rainfall in Zhengzhou city was 552.5 mm, whereas the annual average annual rainfall is 640.8 mm.[1]

The First Affiliated Hospital of Zhengzhou University (ZDYFY) had more than 10 000 beds, 10 899 medical and health technicians, and 7.76 million outpatient visits and 284 300 surgeries in 2019, making it one of the largest and busiest hospitals in China. The Heyi branch of ZDYFY was the hardest hit area during the flood. There were 11 350 inpatients that day, including more than 600 severely ill patients, in need of transfer and rescue.

Hospitals are critical infrastructures in disasters. They should be able to save themselves during extreme weather events such as floods and provide daily and emergency medical services for refugees. In addition to providing care for hospitalized patients, hospitals must manage new patients with flood-related health problems. This requires efforts to minimize flood-related complications such as threats to the power supply, water supply, patient safety, and communication.[2] In China, there are 34 large-scale public hospitals like ZDYFY with an outpatient volume of more than 4 million.[3] Therefore, the performance of hospitals in large-scale flood disasters is very worthy of attention for the discipline of emergency management. This study summarizes the experience of ZDYFY in the 2021 Zhengzhou Flood and provides a reference for large hospitals that may deal with urban floods in the future.

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Table 1. Key interviewee information

ID	Department	Title	Command hierarchy	Main mission
1	Party Committee	Associate dean	Strategic level	Participate in decision-making and command
2	Emergency Department	Director	Campaign level	Coordinate the on-site rescue and contact external rescue forces
3	Hospital Office	General staff	Tactical level	Material allocation and information transmission
4	ICU	Physician	Tactical level	ICU patient transfer
5	Logistics Management Office	General staff	Tactical level	Repair damaged facilities
6	Operating Room	Nurse	Tactical level	Patient transfer

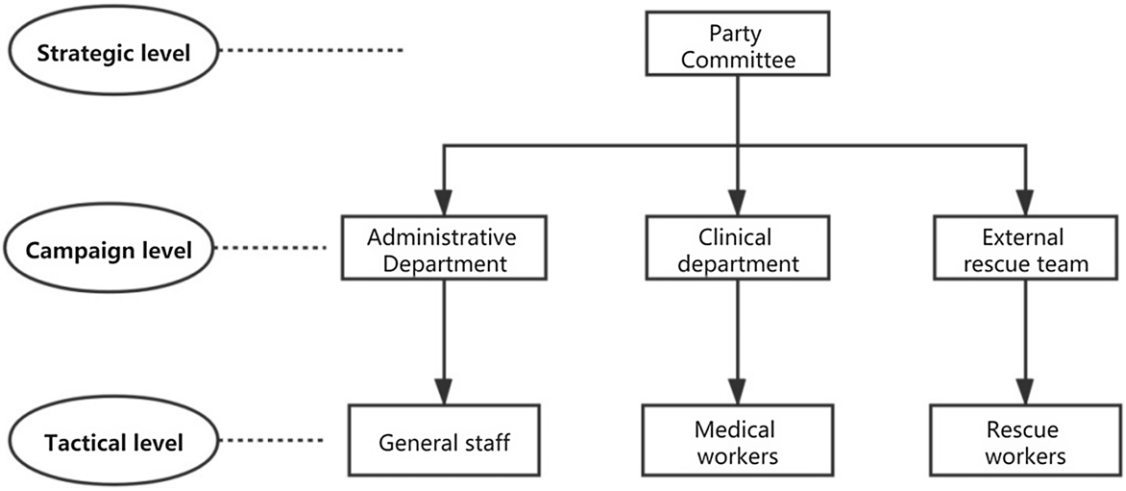

Figure 1. Three-level command system structure.

Method

Study Design

To obtain more detailed and accurate information, we set up a special investigation team, including a professor, associate professor, 1 doctoral student, and 2 graduate students. We designed the qualitative interviews, then conducted a face-to-face conversation.

Sample and Settings

Basically, we adopted the interview method in the qualitative research for this case study. Due to the critical period of post-disaster reconstruction of the hospital during the survey, we were faced with many difficulties in selecting key interviewees. Interviewees were purposively selected to obtain the samples in terms of the 3-level command system of ZDYFY. Judgment sampling was used to recruit 6 participants who were in a relatively key position when the disaster happened to visit.

Data Collection

The semi-structured interviews were conducted by an experienced associate professor and a doctoral student from August to September 2021 at ZDYFY in Zhengzhou city. These in-depth interviews took about 40 minutes each, and the processes were audio-recorded with the consent of the participants, who freely expressed their views on the topic. The sample size was estimated according to available resources, and data saturation was reached among our selected key interviewees, meaning that no new information emerged from the later interviews. This was because, in ZDYFY, the emergency response of the entire hospital was implemented through a 3-level command system. The division of staff at different levels in this system was very clear. Moreover, we selected the staff from key departments, whose experiences were very representative. The representative respondents at each level could represent the experiences and feelings of other employees at that level (Table 1, Figure 1). In addition, we also interviewed some ordinary staff, except the key interviewees, and their descriptions were basically no big difference from those of the key interviewees. The interview guide contained 4 categories of questions: (1) personal information and positions held in the hospital; (2) experience with the Zhengzhou flood in ZDYFY; (3) the successes of ZDYFY during the Zhengzhou flood; and (4) the difficulties faced by ZDYFY during the Zhengzhou flood. Although the survey raised relatively fixed questions, we allowed open answers. To verify the interview guide, we referred to past literature on hospital responses to floods and invited experts in disaster medicine to test the guide. After the interview, audio files were transcribed to check the accuracy of the information.

Secondary Sources

In addition to interviews with key interviewees, secondary sources were also included and provided key information about the flood experience of ZDYFY for which we did not receive from survey responses. These secondary sources were identified through a Baidu search and were reviewed for reliability by our team members.

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Data Analysis

An inductive approach was used to organize and condense the survey, interview, and secondary source data into the 4 stages of disaster emergency management: prevention, preparation, response, and recovery. The transcribed data were read and repeated to focus on the description of the experiences of participants within the data. Content analysis was used according to Graneheim and Lundman's 4 techniques of coding, subcategory, category, and theme.[4] Transcripts were coded and entered into ATLAS.ti 8 software by a trained qualitative researcher. To achieve credibility, peer debriefs were used to validate analyses and findings. To facilitate dependability, the researcher made notes throughout the process of the study and the co-researchers served as auditors, examining processes and products. In addition, the findings avoided language barriers through a process of forward and backward translation from Chinese to English, to ensure that the transcripts accurately identified the participants'experiences.

Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee of Tianjin University, and written informed consent was obtained from each participant. The participants' rights, including confidentiality, were strictly preserved.

Results

Prevention

In a 2020 precipitation ranking of major Chinese cities, Zhengzhou ranked 21st among all 34 major cities, with 681.7 mm per year.[5] Therefore, Zhengzhou hospitals generally lack experience in responding to heavy rains or floods. The Zhengzhou flood brought torrential rains to Zhengzhou city in a short period of time. On July 20, 2021, Zhengzhou's precipitation from 4:00 to 5:00 PM reached 211.9 mm, the highest precipitation in 1 hour since 1951 in China. This means that the scale of this rainstorm was unprecedented for the hospital administrators of ZDYFY. Thus, this is the main reason for their lack of work in the prevention phase.

Preparation

At 9:59 PM on July 19, 2021, the Zhengzhou Meteorological Bureau issued a red rainstorm warning through its media platform. ZDYFY immediately held an emergency meeting before the rainstorm and began to discuss related preparations. The hospital leadership believed that the heavy rain might threaten the hospital's infrastructure and necessitated the transfer of the special patient groups, such as intensive care unit (ICU) patients, to other facilities. At the same time, in addition to the impact of heavy rain on the hospital, the hospital would also need to continue to provide medical services to Zhengzhou city after the disaster to cope with a possible surge in casualties. Therefore, the hospital staff considered the relevant emergency plans for the transfer of patients before the rainstorm on the morning of July 20. These plans involved the ICU, emergency department, and inpatient department.

Response

On the morning of July 20, 2021, ZDYFY launched its emergency plan in response to increasing heavy rain, using a 3-level command system. This emergency plan was made in the preparation stage. See Figure 1 for the specific 3-level command system structure.

From 4:00 to 5:00 PM of July 20, the water level in the hospital continued to rise, and the hospital below the first floor was flooded. To cope with these situations, the hospital had to cut off the main power supply. On July 20, the Heyi branch of ZDYFY had 11 350 inpatients, including more than 600 severely ill patients. Without electricity, the safety of these patients was threatened. Therefore, at the strategic level of the hospital, the decision was made to transfer the patients.

The hospital's strategy was to transfer the critically ill patients first and then transfer the other patients in stages and groups. Among them were ICU patients, whose movement was coordinated by the hospital, and general patients whose transport was arranged by the directors of clinical departments. The ICU patients were mainly transferred to the Zhengdong branch of ZDYFY. Zhengdong branch, about 9 miles from Heyi branch, was less affected by the flood because it is at the high point of Zhengzhou's terrain. The Zhengdong hospital has better medical facilities, but it was located in a less populated area, so there were still many ICU units. Other patients were taken to the Zhengdong branch or other nearby hospitals with receiving capacity. These hospitals were included in the transfer plan in advance. The transfer of ICU patients began at 5:00 PM on July 20. More than 4000 medical staff in the hospital were involved in transporting the ICU patients out of the Heyi branch by manually carrying them on stretchers. Each ICU patient was equipped with a nurse to pinch an airbag by hand to provide life support. Transfer of the non-critical patients began at 3:00 AM on July 21. Patients who could be discharged were discharged, and the rest were transferred. The transfer of patients meant 1 key issue had to be addressed, namely, transportation vehicles. In addition to the hospital's own transport vehicles, such as ambulances, buses were needed. The campaign level of ZDYFY brought in ambulances on temporary secondment from Zhengzhou Emergency Center, as well as buses from a local transport agency. According to the interviews, a total of 68 ambulances and more than 40 buses participated in the transfer. Due to the deep stagnant water in many places on the roads, ZDYFY also called for 10 kayaks from a local emergency management agency. Clinical department directors at the campaign level played an important role in managing these transfers. By July 22, all 11 350 inpatients had been evacuated, including more than 600 ICU patients.

The transfer method of patient information was verbal communication between the responsible doctors and the destination doctors. When the information system of the Heyi branch was restored, the detailed information of the patients was transferred to the receiving hospital. After the transfers were completed, the destination hospitals were responsible for the follow-up treatments of the patients, and the patients would not be transferred back to the Heyi branch.

Recovery

The first difficulty faced by ZDYFY in post-disaster recovery was the water drainage. The rescue teams from Hunan and Hubei Provinces joined the pumping operation in the following days. After the pumping work was basically completed, the power restoration work began on July 25.

The Heyi branch of ZDYFY reopened on the morning of July 26 and received more than 8000 outpatients on that day. Electric fans and blocks of ice were placed in each consulting room for cooling. The procedures of registration, payment, and medicine collection were also restored.

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According to our interview, after recovering normal medical services, ZDYFY made plans to carry out training on disaster preparedness skills throughout the hospital and a series of activities to improve the hospital's vulnerability, including redesigning the hospital's electrical system and increasing the hospital's emergency supplies reserve.

Discussion

Our study was among the first to apply the experiences of staff to document the transfer of patients on such a large scale after a flood. It was also the event of one of China's largest hospitals coping with the country's devastating floods. The process of hospital emergency management regarding flood disaster preparedness was assessed and described in this study. We tried to follow ZDYFY' s disaster plan for the Zhengzhou flood to truly reveal the process of this event, as far as possible, so the 4 stages of disaster emergency management were applied. The analysis of our surveys and interviews showed valuable lessons about flood preparedness and mitigation through the direct experience of ZDYFY with the huge flooding. We believe these lessons can help the mega-hospitals improve their disaster preparedness and provide guidance for the policy-makers to strengthen governmental intervention in hospital disaster response in the future. The results indicated that the most remarkable hospital emergency response success was maintaining adequate leadership. Additional successes included hospital staff dedication and cooperation.

How well a hospital responds to a crisis is associated mainly with the leadership team—leadership that is agile, flexible, and critical in developing an organization's resilience.[6] The strategic level of ZDYFY allowing for changes and rapid decision-making to occur when the flood that exceeded people's expectations happens enables teams to best function and thrive in times of a crisis. For example, emergency mobilization of rescue vehicles throughout the city assisted in the transfer of patients, and coordination of rescue forces from other provinces participated in the emergency repair of the hospital's infrastructure. In June 2001, the tropical storm "Ellison" caused a hospital in Houston to be closed for 38 days.[7] In comparison, ZDYFY took only 6 days from the beginning of the flood to reopen. Hence, features administration needs to be considered in preparation for the floods. This includes that preparation and training are not limited to the emergency staff only but also involve the management of hospital staff. Besides, effective communication through top-down management is needed. This ensures the flood information can be communicated smoothly and accurately. Coordinating rescue efforts from other agencies to transport patients will also need to be recognized as an important part of leadership in the future. At the same time, effective human resource management is important to ensure that hospitals are adequately staffed during floods to ensure continuity of operations.

The hospital staff is one of the main forces to deal with the flood in hospitals and plays a very important role in effective transferring. The number and the level of emergency skills and the spirit of dedication of the staff determine the emergency response capacity of a hospital, to some extent. During the Zhengzhou flood, more than 3000 ZDYFY staff members showed extreme dedications. The staff of ZDYFY generally worked more than 12 hours without incentives during the flood. Due to the emergency and power damage, there were no areas for rest. The staff generally took short breaks and ate in the corridors. Due to the failure of the electrical system, the physical workload of the hospital staff was very heavy, and some medical staff exhibited symptoms of hypoglycemia and hypothermia. As the hospital planned to reopen in a short period of time, the staff also needed to invest much labor in the recovery phase after the flood. Previous studies have shown that hospital workers undergo a double burden during disaster response and struggle between responsibilities toward their family and hospital duties.[8] We found that when respondents felt safe, they were generally more positive, saw their experience as meaningful, and felt a sense of belonging to a supportive hospital. In our interviews, we also found that some interviewees expressed hope that the hospital could establish some relevant rewards and compensation mechanisms in the future. However, it is not enough to rely solely on individual dedication. Incentive strategies can promote disaster preparedness and effectively increase the flexibility of hospital staff to respond to disasters. Contributions of young people also can be promising and forward looking when regarding disaster resilience and could be a valuable asset in the design of local hospital plans.[9] It is also important to integrate employee preparedness into the overall disaster preparedness, such as developing individual disaster preparedness plans and training in psychological comfort for employees. This may help reduce the tension between personal and professional responsibilities. Staff should also be given space to work, as this can be a strategy that helps bring out their initiatives and competence.

Collaboration is an important part of a hospital's response to flooding, which maximizes the resources of the entire hospital, both internal and external. Zhengzhou city lacked a similar specialized agency such as the Catastrophic Medical Operations Center (CMOC) during the flood. Thus, ZDYFY had to perform efficient and cooperative rescue works. In our interviews, we found that medical staff in ZDYFY cited achievements of cooperation in 3 areas. First, communication and collaboration among the 3 branches of ZDYFY ensured the smooth transfer of patients from the Heyi branch to the other branches. Second, to deal with the flood, the hospital temporarily established a 3-level command system. This command system ensured the execution of all emergency work. Third, the cooperation of internal and external rescue forces in the hospital effectively improved the efficiency of patient transfers. Our findings also showed that communication issues served as a barrier to reporting to work. Communication plays a key role in disaster response, providing emergency respondents with relevant information on appropriate actions to take. However, communication methods often break down, making it difficult to transmit and receive information during disasters. As reported by several interviewees, a lack of information led to confusion over responsibilities among staff between different departments during the Zhengzhou flood. As normal communications are likely to fail during floods, hospitals should have some tools like satellite phones on hand, consequently strengthening communication capacity. For small- and medium-sized hospitals, the local government should establish a special organization to aid with hospital communication and cooperation during disasters.[10]

Despite these successes, hospitals still experienced challenges, such as prolonged roadway flooding that restricted the transportation, infrastructure issues, and a shortage of training and drills.

In the event of a flood, hospitals need to prepare beforehand for possible transportation problems. Like the flood situation in other parts of the world, many major roads near the hospital were flooded. The deluges largely prevented the use of traditional transportation methods such as cars and ambulances. Hence, other

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transportation methods were needed, such as helicopters and kayaks. This caused efficiency to decrease. In our interviews, some interviewees expressed the hope that the government could improve the road design near the hospital, thereby strengthening the hospital's emergency rescue capabilities during disasters.

Floods can easily damage hospital facilities or interrupt the use of these facilities. Thus, the hospital must be designed and built to prevent potential disruption of function caused by flooding. Many hospitals in China have adopted underground designs for their infrastructures, which make them very fragile in the face of floods. Faced with this situation, the hospital must regularly check the drainage system and sewage system or transport important equipment to higher areas based on the structural design. To be more specific, transformers, emergency generator, and electrical room must be relocated above grade to make sure they're protected from flooding. The structural elements of the hospital building, such as the safe location, design, and structure, are important considerations in allowing the hospital to withstand flooding. We think we can plant trees and other large plants near the hospital, because large plants can intercept the rain and slow its flow into the building and the drainage system. Therefore, the design of improved infrastructure should be made to improve disaster response capabilities for hospitals.

The evacuation of hospitals due to disasters is not a rare event. From 1979 to 2009, 69 hospitals around the world were forced to evacuate due to natural or human-made disasters.[11] When a hospital is facing a disaster, evacuation is a complex and arduous task. It is necessary not only to evacuate the patients but also to collect equipment and documents. A large-scale evacuation will also affect the mental health of medical staff and patients. Although ZDYFY successfully transported 11 350 inpatients within 2 days, some patients still showed anxieties according to our interviews. Medical staff were also nervous due to the high workloads. Training and drills could be the solutions. Hospital staff should receive training in emergency risk communication, ensuring hospitals' resilience to disasters. In addition, training in non-structural risk mitigation is essential for staff in all hospitals for improving non-structural mitigation practices and address preparedness and possibilities for action to reduce risks and losses.[12] Beyond that, the local government and multi-stakeholder coordination are crucial in transporting thousands of inpatients. We therefore advise ZDYFY and the local government agencies to strengthen the emergency response sector, including thorough planning for safe evacuation. In addition, in the process of transferring non-critical patients to other hospitals, the patient data were not completely transferred, and most patients had to rely on the oral narration of medical staff, which could affect the quality of medical services after the transferring. Accurate data on transported patients are essential to ensure a timely and specific medical response after the transferring. For this reason, hospitals need to develop an information technology system to organize and maintain up-to-date inpatient databases. At the same time, it is also necessary to establish cloud servers and standby servers to ensure the security and availability of data.

There are many large hospitals with thousands of beds in China, and they will likely face a similar situation as ZDYFY in the future. The current state of flood preparedness and mitigation in ZDYFY is rather advanced and mature, validated by the achievement of transferring 11 350 inpatients and response to the Zhengzhou flood. Through our research, hospitals and medical units in China and even other countries around the world can take advantage of ZDYFY' s experience to increase their flood response capacity with fewer financial and various resources and can address the challenges described in this study.

Limitations

This study had limitations. First, the study focuses on very large hospitals only. The management model of this hospital is particular to its scale. There are many financial and staff resources available for flood control and restoration works, which may not be applicable to other small- and medium-sized hospitals in the region. Second, the interviewees in the hospital may tend to emphasize the successes achieved rather than the difficulties and challenges, which may bias the survey results.

Conclusion

The experience of ZDYFY provided insight into a huge hospital's journey in a catastrophic flood. To effectively respond to the flood, forward-thinking leadership provided a strong execution and allowed the hospital to transfer the high-risk patients on landfall. Besides, effective collaboration through top-down management was needed. This ensured the working flow to be executed properly. In addition, staff motivation was also critical. However, many challenges were highlighted in this study. By adopting effective strategies, hospitals can overcome these barriers, such as design agreements with other hospitals for patient transfers. Although we cannot prevent natural disasters from occurring, personnel training and a well-organized disaster management plan can lessen the disruption. This study revealed a better and deeper understanding of the flood disaster preparedness among hospitals in China.

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Competing interests. No potential conflicts of interest were reported by the authors.

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