Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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SPECIAL ISSUE ON GLOBAL RESPONSES TO COVID-19 PANDEMIC: CHALLENGES AND OPPORTUNITIES

REVIEWS

Hospitals' responsibility in response to the threat of infectious disease outbreak in the context of the coronavirus disease 2019 (COVID-19) pandemic: Implications for low- and middle-income countries

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ABSTRACT

The WHO declared the coronavirus disease 2019 (COVID-19) outbreak as a public health emergency of international concern on January 30, 2020, and then a pandemic on March 11, 2020. COVID-19 affected over 200 countries and territories worldwide, with 25,541,380 confirmed cases and 852,000 deaths associated with COVID-19 globally, as of September 1, 2020.[1]

While facing such a public health emergency, hospitals were on the front line to deliver health care and psychological services. The early detection, diagnosis, reporting, isolation, and clinical management of patients during a public health emergency required the extensive involvement of hospitals in all aspects. The response capacity of hospitals directly determined the outcomes of the prevention and control of an outbreak.

The COVID-19 pandemic has affected almost all nations and territories regardless of their development level or geographic location, although suitable risk mitigation measures differ between developing and developed countries. In low- and middle-income countries (LMICs), the consequences of the pandemic could be more complicated because incidence and mortality might be associated more with a fragile health care system and shortage of related resources.[2–3] As evidenced by the situation in Bangladesh, India, Kenya, South Africa, and other LMICs, socioeconomic status (SES) disparity was a major factor in the spread of disease, potentially leading to alarmingly insufficient preparedness and responses in dealing with the COVID-19 pandemic.[4] Conversely, the pandemic might also bring more unpredictable socioeconomic and long-term impacts in LMICs, and those with lower SES fare worse in these situations.

This review aimed to summarize the responsibilities of and measures taken by hospitals in combatting the COVID-19 outbreak. Our findings are hoped to provide experiences, as well as lessons and potential implications for LMICs.

1. Roles of hospitals in infectious diseases prevention and control

In addressing the evolving needs brought by emerging or reemerging infectious diseases, such as severe acute respiratory syndrome (SARS) and avian influenza, the WHO revised the *International Health Regulation* (IHR [2005]) and promulgated the updated version in 2005. IHR (2005)[5] specifically required each country to develop national public health response capacity, including that for hospitals and other important operational services. Thereafter, countries, especially developed one, revised their own related regulations and laws, and developed detailed implementation plans for health care facilities.[6–8]

In general, hospitals provide services in three main areas: preventive services, therapeutic services, and linkages to communities for health concerns.[9] In the field of infectious diseases, hospitals were the first line of defense for detecting potential outbreaks of an emerging or reemerging infectious disease, and medical staff on duty was firstly to detect and report emergency events, both in high-income countries and low- and middle-income countries (LMICs).[10] A systematic review identified seven core areas in hospitals' preparedness for biological events, such

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as the SARS and influenza pandemic, namely, planning, surge capacity, communication, training and education, medical management, surveillance, and standard operation process.[11] In addition, an Africa Task Force for Coronavirus Preparedness and Response was established with six main responsibilities, half of which were related to hospitals: laboratory diagnosis and subtyping, surveillance (including screening at points of entry and cross-border activities), infection prevention and control in health care facilities, clinical treatment of patients with severe coronavirus disease 2019 (COVID-19), risk communication, and supply chain management and stockpiles.[12]

Taking China as an example, the country owns over 33,000 hospitals with 6.5 million beds, admitting nearly 3.6 billion visits per year.[13] After the SARS outbreak in 2003, the Chinese government revised the *Law of the People's Republic of China on the Prevention and Control of Infectious Diseases*, as well as launched a series of new regulations and action plans. The relevant laws and regulations clearly defined hospitals' responsibilities during infectious disease outbreaks and public health emergencies. China's hospitals are responsible for the medical treatment of infectious diseases as well as the prevention and control of the spread of disease. Hospitals have mandated responsibilities in strictly implementing management systems and operational protocols to prevent medical-borne or hospital-acquired infections. They are required to establish specialized departments or positions in charge of reporting outbreaks, prevention and control of infectious diseases, risk monitoring, safety and security, disinfection and isolation, and disposal of medical waste in medical facilities. Hospitals also carry the obligation to take control measures in a timely manner and follow the instructions of the National or Regional Emergency Response Commanding Center or Emergency Operation Centers.

The roles and responsibilities of hospitals in China in the prevention and control of infectious diseases are summarized in four aspects: surveillance, treatment, prevention and control, and preventive services delivery (Table 1).[14]

Table 1
Hospitals' roles and responsibilities in China for prevention and control of infectious diseases.

Responsibility		Content of work
Surveillance	• Diagnosis	▪ Clinical diagnosis ▪ Laboratory diagnosis
	• Reporting	▪ Statutory infectious disease (39 diseases in 3 categories) ▪ Related syndromes (including Influenza like illness, ILI, and Acute flaccid paralysis, AFP) ▪ Epidemic outbreak (including hospital-acquired infections)
Treatment	• Clinic	▪ Timeliness ▪ Normative
	• Inpatient	▪ Timeliness ▪ Normative
Prevention and control	• Disinfection	▪ Air and environment ▪ Surface of facilities ▪ Medical devices ▪ Items used by confirmed cases ▪ Excrement, secretion, and vomit ▪ Transit ambulance
	• Pre-diagnosis and triage	▪ Responsible departments ▪ Diagnostic criteria ▪ Scope of subjects
	• Isolation	▪ Principles ▪ Measures
	• Protection	▪ Protective supplies ▪ Vaccination
	• Medical waste	▪ Disposal according to various categories
Preventive services	• Screening	▪ General screening ▪ Selective screening
	• Intervention	▪ Vaccination ▪ Medication
	• Health education	▪ Characteristics of infectious disease ▪ Risk factors

2. Unique problems faced by hospitals in LMICs under the COVID-19 pandemic

The laws and regulations have been gradually amended and improved in LMICs after the outbreaks of SARS, influenza, and Ebola.[6–8,15–19] Hospitals are required to make detailed action plans for emergencies or follow a detailed national action plan, which must include procedures for patient treatment and transport, cooperation with national or local Centers for Disease Prevention and Control (CDC), prevention of hospital-acquired infection, reporting of confirmed cases, diagnosis and treatment experiences, as well as research and international exchange.[15–18,20] However, the problems arising from outbreaks, which are generally characterized by a wide range of effects and high pathogenicity, are much different compared with ordinary epidemics of infectious diseases, such as seasonal influenza. Hospitals in LMICs face a number of challenges in the context of this novel COVID-19 pandemic.

Hospitals in the affected countries and regions have suffered crowding out of health services at different levels. Hospitals in non-epidemic areas are caught between preventing hospital-acquired infections and providing routine health services. Poor handling of this balance may result in a hospital with either a cluster of infection events[21–22] or the increased burden of chronic diseases owing to delayed health care.[23] This dilemma affects hospitals in all countries regardless of income level, but in LMICs, where the emergency response capacity is far from sufficient, the impact is typically much greater. For example, in Haiti, there are fewer than 30 intensive care units (ICUs) that can treat patients who require artificial ventilation, and many ICUs lack oxygen concentrator units.[4] Epidemics may further degrade ICUs capabilities when staff members fall ill. In a large-scale outbreak, shortages in equipment and medications can further limit an ICU's ability to provide standard care.[24]

Many outpatient clinics and wards had also closed or stopped admitting inpatients for the following reasons: decreased medical capacity because of the demand for human and material resources to support the epidemic areas,[25] insufficient personal protective equipment,[26] and susceptibility of vulnerable patients or older adult population who are at higher risk of infection.[27] Consequently, during the pandemic, hospitals, whether in epidemic areas or not, have experienced a temporary shortage in capacity for health service delivery. The lack of confidence in public health authorities and systems may have also exacerbated the situation.[4]

The COVID-19 outbreak has demonstrated the importance of basic preparedness and capacity building for targeting the threat of infectious diseases. Beyond these, more response measures could help achieve better control of the outbreak.

3. Responses of hospitals to the threat of the COVID-19 outbreak

In response to the unique problems brought by the COVID-19 epidemic, considering both national requirements and local circumstances, hospitals in China have responded in the following ways.

3.1. Collaboration of hospitals in epidemic areas

In responding to the COVID-19 outbreak, local medical resources in most of the affected areas were extremely strained. In the initial response to the outbreak in Wuhan City and Hubei Province, China mobilized human resources and medical supplies to the outbreak areas from other provinces. On February 9, the National Health Commission of the People's Republic of China, convened 17 medical teams at the most severely affected areas. Each team took over a specially designated ward

of local hospitals (including newly constructed ones) within 24 h and admitted and treated more than 800 patients within 48 h.

Therefore, from these experiences, multiple measures need to be taken in a limited time frame:

First, hospital facilities and the adaptability of medical staff need to be upgraded. New infectious disease wards need to be constructed, or general wards renovated, with clearly divided districts of contaminated areas, clean areas, buffer zones, and so on. Medical staff not originally from local hospitals needs to be trained on the landscape, facilities and physical environment, working processes, and core systems of the hospital. Training on the prevention and control of hospital-acquired infections is also essential.

Second, medical assistant teams also need to bring large quantities of supplies from hospitals to the epidemic areas to fill the shortage of supplies caused by the large number of critically ill patients, including protective supplies, medical equipment, and medical instruments. Large medical equipment (including ventilators) can be managed by local hospitals.

Third, collaborative management must be conducted to ensure normal daily operation. Medical assistant teams come from different institutions with various cultural backgrounds, and as such, they need to comply strictly with the core system of local hospitals. Daily meetings should be held by local hospitals to resolve daily problems, build rapid response pathways, and discuss deaths and difficult cases.

Finally, the COVID-19 epidemic is characterized by a high number of critically ill patients, a high number of older patients, serious pre-existing diseases, rapidly changing disease course, and poor prognosis for critical cases. According to their characteristics, confirmed cases must be classified and managed, especially paying attention to critically ill patients. In addition to early evaluation, detection, and treatment, hospitals must develop salvage techniques, including tracheal intubation, continuous renal replacement therapy, extracorporeal membrane oxygenation, prone ventilation, and intra-aortic balloon pacing, to form a closed-loop management model for the treatment of critically ill patients. As for the mildly or moderately ill patients, the novel public health concept of shelter hospitals should be implemented, according to the detailed response approach explained by Chinese scientists.[28]

3.2. Specific response measures of hospitals beyond national emergency action plan

3.2.1. Incident command system

After the outbreak, hospitals at all levels should set up a hospital-level incident command group, with a senior hospital leader serving as the group director and all relevant departments included in the group, in accordance with the requirements and emergency action plans of health authorities. Some hospitals have demonstrated further refining the establishment of goal-oriented management teams by breaking departmental boundaries to facilitate the efficient coordination of resources.

3.2.2. Critical cases treatment and management

During the initial COVID-19 outbreak, the patients who required ventilatory support outnumbered the available ICU beds. In resource-limited countries, ICU beds and personnel trained in critical care are limited to tertiary hospitals, as assessed in the Republic of the Gambia.[29] During the peak of the COVID-19 outbreak in China, the number of patients who required ventilatory support outnumbered the available ICU beds.[30] As the epidemic spreads, the number and capacity of ICUs in other LMICs may also be challenged and need to be upgraded.

3.2.3. Communication

The timeliness, accuracy, and completeness of information on epidemic prevention and control are especially important. Such information facilitates informed decision-making and effective collaboration within hospitals and help gain the understanding and trust of the public.[2,31] During the COVID-19 epidemic, some hospitals set up exclusive departments (or temporary teams) to standardize the processing of information and unify the dissemination of authoritative information, so as to avoid cumbersome communication, duplication, contradictions, non-standard data, and inconsistent processes.

Communication includes: (1) briefing of the hospital staff on the various emergency policies, such as pre-screening and triage, admission criteria, infection prevention and control measures, and updates for treatment programmers; (2) collecting and collating of relevant information and sharing of necessary data (e.g., material stocks, patient profiles) with government and health authorities, hospitals in the same alliance, and CDC; (3) provision of information to different target audiences with various levels of expertise and knowledge, such as patients, workers, and ordinary public;[31] (4) training of spokespersons; and (5) ensuring of information and data security.

3.2.4. Continuity of essential health services and patient care

Even during an epidemic, the public will continue to have medical needs, such as emergency care, emergency surgery, maternal and child health care, and follow-ups of chronic diseases. As such, hospitals must ensure the basic medical needs of the public while protecting them from infection. After a short period of closure, along with conducting strict prevention and control measures, all hospitals should reopen essential clinic and inpatient admission, with a detailed and updated list of available medical services during the epidemic. For specific patient groups, many general or specialty hospitals have proposed management responses, including cardiovascular diseases,[32] oncology,[33–35] dental care,[36] ophthalmic care,[37] maternal and child health care,[38–39] and dialysis centers.[40]

3.2.5. Human resources

Hospitals of all types should unify their human resources for emergency response and manage them according to their duties. Hospitals can set up a reserve of medical, nursing, and management assistant teams for external epidemic support, as well as set up a reserve of emergency teams according to internal hospital demand. Human resource departments should focus on continuously standardizing training to keep abreast of the latest treatment guidelines and prevention and control requirements. Beyond this, ensuring preventive equipment for frontline staff, optimizing the scheduling mechanism,[41] and evaluating and providing support for the mental health status of the medical staff[42–43] are also key points.

3.2.6. Logistics and management of relevant supplies

As the epidemic progresses, the demand for medical emergency supplies may surge in both variety and quantity. The disruption of supply chains and depletion of stock (e.g., medical supplies and equipment) may occur sooner or later in both high- and low-resources settings.[2,44] Hospitals have experienced a severe shortage of supplies, especially for protective materials, and screening, treatment, life supportive, and sterilization equipment. Therefore, hospitals should tackle this problem using both cost-cutting and source-attracting approaches. In terms of cost cutting, an inventory of existing hospital supplies can be carried out, focusing on supporting high-risk positions, reducing waste, and forecasting future daily consumption.[45] Meanwhile, timely communication with suppliers should be made, temporary agreements signed if necessary, and donations accepted in accordance with legal requirements. Among these actions, the risks should be acknowledged to avoid potential bribery and corruption, including risks related to subject compliance during public offering, integrity, material quality, risk management, and financing.[46]

3.2.7. Hospital-acquired infection prevention and control

Hospital-acquired infections are among the most important risks during an outbreak or pandemic; therefore, an operational infection prevention and control policy is essential to minimize the risk of transmission of health care-associated (nosocomial) infection to patients, hospital staff,

and visitors. In addition to previous regulations, hospitals have carried out a range of measures to avoid infections according to local conditions, in compliance with two newly established guidelines for COVID-19.[47–48] The measures include the establishment of an emergency management system, development of a practical prevention and control system, and assessment of predicted risks based on data monitoring.[49–51]

Hospital-acquired infections should be strictly prevented and controlled by carrying out protocols, such as pre-screening, optimizing the existing physical layout and visiting flow of clinics, delineating hierarchical management by infection zones, rationalizing spatial dynamics, rigorous screening of medical staff and inpatients with other diseases, as well as daily monitoring.[11,31,52]

Preventive disinfection measures should be implemented based on transmission pathways,[53–54] including different protection requirements for medical personnel in terms of exposure risk classification, on-site disinfections targeted at specific pathogens, and focusing on blind areas of management (e.g., toilets or air conditioning systems).

Given that vaccines for COVID-19 are still in development, governments must protect their susceptible population. Protective isolation should be implemented among this population as well as immunity enhancement through balanced diet or other measures. Additionally, attention should be paid to the tendency of overprotection to avoid unnecessary waste in the prevention and control of hospital-acquired infections.

3.2.8. Online health services and online offices

In the COVID-19 pandemic, most authorities worldwide have recommended avoiding, as much as possible, patients' elective visits to hospitals as well as the judicious use of the operating room, to mitigate the stress put on the health care system.[55] With previous successful experiences in the management of acute infectious respiratory epidemics, such as SARS and Middle East respiratory syndrome (MERS), telemedicine or telehealth plays an important role in the time of the COVID-19 epidemic.[56] Online health services could help screen and distinguish possible suspected patients from other common patients, thereby helping relieve the anxiety and panic among the public,[57] provide the necessary help to follow-up patients who cannot come to the hospital owing to the epidemic, and ensure pharmacological services for patients with chronic and common diseases. Convenient methods, such as home delivery or pickup at designated points, have also been provided in some areas.[58] Community pharmacists in LMICs, being the most accessible health care professionals and the first contact point of patient engagement with the health system, have also contributed to health care delivery[44] though balancing the supply and demand of medicines and consumables as well as testing and diagnosis, and in the future, vaccine delivery.

In addition, teleconsultation can be conducted on a regular basis for patients in epidemic areas.[59] For medical students who cannot return to school owing to the epidemic, online education and learning have been proven effective and can be implemented widely.[59] For administrative staff who are not necessarily working in offices, working remotely or at home can reduce the risks of infection as well as the operational costs and should be encouraged.

4. Conclusions and suggestions

The COVID-19 pandemic has significantly impacted the world. The preparedness and response of hospitals, as the front line for combating the pandemic, are of utmost importance in the case of a public health emergency. LMICs are facing enormous challenges owing to limited resources and fragile systems. Hospitals in LMICs, especially in China, as the early breakout area, have implemented some innovative procedures during the epidemic to decrease the risk of further transmission. With the long time-consuming for the research and development of vaccine for COVID-19, and the coming flu season, hospitals should consider adhering to the measures discussed here, take advantage of the experiences and lessons learned from the early phases of the pandemic, and adjust their response measures continuously to cope effectively with potential public health emergencies.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

JZ, XL and ZZ conceived the study. JZ and XL searched the literature, organized the materials, interpreted the results, and drafted the manuscript. YJ and ZZ made critical revisions on the manuscript and provided implications of the study findings.

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