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Review Article

Hospital biosecurity capacitation: Analysis and recommendations for the prevention and control of COVID-19

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ABSTRACT

The outbreak of the coronavirus disease 2019 (COVID-19) in December 2019 highlighted several concerns regarding hospital biosafety capacitation in the People's Republic of China, although the epidemic is now under control. This study examined the primary problems related to hospital biosecurity, including the absence of a hospital emergency system, inadequate management and control of nosocomial infection, limited hospital laboratory capacity, and poor hospital admission capacity. Accordingly, this study puts forward the following countermeasures and suggestions for hospitals to deal with future biosecurity events, such as a major epidemic: first, biosecurity management systems and emergency response mechanisms in hospitals need to be set up; second, the investment and guarantee mechanisms for hospital biosecurity construction should be improved; third, the capacity building of biosecurity incident management requires special attention in general hospitals; and finally, comprehensive plans need to be developed for the integrated construction of medical treatment and prevention facilities through disease-control systems.

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Contents

1. Introduction ........................................................................................................ 6
2. Concerns about hospital biosecurity construction ............................................. 6
   2.1. Hospital emergency response system needs to be improved to cope with major public emergencies ........................................... 6
   2.2. Insufficient hospital infection management and control capabilities put medical staff at high risk ............................................. 6
   2.3. Inadequate laboratory conditions and capabilities affect timely testing and clinical diagnosis ............................................. 7
   2.4. Hospital admission conditions cannot meet emergency treatment requirements for large-scale infectious diseases ................ 7
3. Recommendations ............................................................................................. 7
   3.1. Capacity building for biosecurity management systems and emergency response mechanisms in hospitals ............................... 7
   3.2. Improve investment and guarantee mechanisms for hospital biosecurity construction ....................................................... 7
   3.3. Proceed with the capacity building of biosecurity incident control in general hospitals ............................................................ 8
   3.4. Develop overall plans for integrated construction of medical treatment and prevention hospitals and disease-control systems .... 8
4. Open access ....................................................................................................... 8
5. Availability of data and material .................................................................... 8
6. Funding ............................................................................................................. 8
7. Consent for publication .................................................................................... 8
8. Acknowledgments ............................................................................................ 8
9. Competing interests ......................................................................................... 9

Abbreviations: COVID-19, Coronavirus disease 2019; SARS-CoV-2, Severe acute respiratory syndrome coronavirus 2; SARS, Severe acute respiratory syndrome; H1N1, influenza A virus subtype H1N1.
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1. Introduction

In December 2019, the coronavirus disease 2019 (COVID-19), first detected in Wuhan City, Hubei Province, People's Republic of China, rapidly spread to many provinces and cities across the country. At 00:00 on April 21, 2020, the National Health Commission reported a total of 82,788 confirmed COVID-19 cases, including 4632 deaths and 77,151 cured cases from 31 provinces (autonomous regions and municipalities); in Hubei Province alone, 68,128 confirmed cases, 4512 deaths, and 68,128 cured cases were reported. In contrast to the severe acute respiratory syndrome (SARS) and influenza A virus subtype H1N1 (H1N1), infections that occurred in 2003 and 2009, respectively, in the People's Republic of China, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), causing COVID-19, is a new pathogen characterized by the following features: unknown animal origin, strong transmissibility, high susceptibility of the general population, and uncertain mortality rates in high-risk populations. The lack of an effective treatment for severe COVID-19 has been detrimental to both the society and the economy. Moreover, the epidemic has exposed grave biosecurity governance inadequacies. A greater concern is that the slow early warning of the epidemic has seriously undermined not only the effectiveness of the preventive and control measures but also the treatment at the later stages of infection. Therefore, to ensure public health, safeguard national security, and maintain the long-term national stability, it is essential to incorporate biosecurity into the national security system, systematically plan the construction of a national biosecurity risk-control and governance system, and comprehensively improve the national biosecurity governance capacity.

2. Concerns about hospital biosecurity construction

After the COVID-19 outbreak, the People's Republic of China set up a leading group to ensure a timely response to the epidemic. The state, army, and local governments at all levels responded forcefully, and the military-civilian joint prevention and control mechanism was rapidly established to undertake decisive measures in order to prevent the import, spread, and transmission of the epidemic and thus block the nationwide SARS-CoV-2 transmission. The majority of military and civilian medical workers have fought hard at the frontline to achieve the phased goals of “double decreases” (increased treatment and cure rates) and “double increases” (decreased infection and mortality rates), and obtained remarkable results regarding epidemic prevention and control. However, in the fight against COVID-19, many problems emerged in local hospitals due to a long, unprecedented epidemic. These problems indirectly reflected that hospitals have several shortcomings when it comes to infectious disease prevention and treatment as well as hospital biosecurity construction. Therefore, we aimed at evaluating these problems and developing suitable countermeasures.

2.1. Hospital emergency response system needs to be improved to cope with major public emergencies

After the COVID-19 outbreak, all provinces (autonomous regions and municipalities) across the country initiated first-level responses to public health emergencies to ensure that the momentum of the epidemic was effectively contained. Nevertheless, medical institutions at all levels, especially hospitals, demonstrated a weak response to the epidemic in the early stages, due to the following four reasons.

First, the biosecurity emergency response force was insufficient. Although hospitals set up infection control or disease prevention departments, the clinicians who had a poor understanding of the disease implemented inappropriate measures at the early stage; thereby, the best time point for disease control had already been missed. On one hand, it was a result of the shortage of personnel skilled in biosecurity, on the other hand, it was the lack of professional knowledge and skills, such as surveillance and early warning, sample collection, disinfection and quarantine, and protection training.

Second, the interactive emergency response mechanism did not function smoothly. Owing to the large number of hospital patients, poor information exchange among medical, disease control, and scientific research institutions caused doctors to have scant knowledge of the epidemiological characteristics, transmission patterns, and human-to-human transmission of the SARS-CoV-2 infection. These factors contributed to disappointing treatment results.

Third, the emergency reserves were inadequate. Owing to the defective emergency reserve system and the large number of people quarantined for prevention and protection, there was a nationwide shortage of masks, goggles, protective clothing, and quarantine clothing in the hospitals.

Finally, the hospital infectious disease monitoring network system did not play an early warning role in the early stage. Since 2003, the People's Republic of China has successively established a direct epidemic reporting system, pathogen surveillance system, unknown pneumonia case surveillance system, and symptom surveillance system, in order to facilitate early detection of newly-emerging infectious diseases. However, judging from the response to COVID-19, many of these systems did not play an adequate role during the early warning.

2.2. Insufficient hospital infection management and control capabilities put medical staff at high risk

COVID-19 is transmitted from the carrier to others mainly through droplets and close unprotected contact; there is also a possibility of airborne transmission through aerosols produced during medical procedures. Therefore, COVID-19 can be detected in the ambient air of medical institutions, to which everyone is generally susceptible. Human-to-human transmission and medical staff infection have also been confirmed. By February 20, 2020, a total of 2055 medical staff in 476 hospitals reportedly had contracted COVID-19; most of them (88%) were from Hubei Province and diagnosed during the early stage of the outbreak in Wuhan. Therefore, medical staff biosecurity protection is of particular significance. As infected patients could not be detected in time during the incubation period at the outset of the epidemic, medical staff failed to implement graded protection and standard prevention protocols, which resulted in nosocomial infections. After identifying the confirmed cases, the shortage of protective materials or gear, and the lax implementation of hospital rules and regulations on nosocomial infections further exposed medical staff to the risk of nosocomial infection. In addition, nosocomial cross-infection among ordinary patients was not given due importance. Cross-infection among patients or between doctors and patients is caused by poor conditions at the fever clinic or inadequate man-
management of nosocomial infection. Particularly, in the treatment of COVID-19, the vast majority of the non-infectious and respiratory professionals had limited knowledge of the disease and its prevention and control. This contributed to the growth of the nosocomial infection rate, accounting for a large proportion of COVID-19 cases. One example of this is the earliest nosocomial event at the Department of Neurology of the Wuhan Union Hospital. 17

2.3. Inadequate laboratory conditions and capabilities affect timely testing and clinical diagnosis

One of the gold standards for confirming the diagnosis of patients with SARS-CoV-2 infection is the etiological evidence, which involves nucleic acid testing through real-time fluorescent polymerase chain reaction. 13 However, the COVID-19 epidemic has exposed several problems with regard to laboratory conditions and capabilities. First, there is a lack of biosafe laboratories in hospitals. The COVID-19 tests need to be carried out in second-grade biosafety laboratories, 18–20 which are unavailable in many hospitals. Moreover, hospitals that have these laboratories might be unable to obtain the testing qualification from relevant state departments in time, resulting in failure to detect, diagnose, and treat the disease in time. Second, there is a lack of hospital testing materials. Due to improper sampling, non-standard protocols, and stability and reliability concerns raised by several hastily-developed new kit products at some hospitals, the positive detection rate was low. In addition, some patients had residual viral loads detected in stool samples after being discharged from the hospital, resulting in repeated positivity 4 and a risk of repeated infection spread.

2.4. Hospital admission conditions cannot meet emergency treatment requirements for large-scale infectious diseases

During the epidemic, several hospitals were facing difficulties with being obliged to expand capacities for quarantine and admission purposes in a short period. As of February 20, 50,000 patients received treatment across the country, and hospitals strived to expand hospital bed capacity. 2 The first difficulty was the limited capacity for housing patients with infectious diseases. For instance, despite the availability of 45 designated hospitals in Wuhan, a large number of patients were waiting for beds even weeks after the outbreak. Two temporary hospitals have been built, and 10 square cabin hospitals were quickly set up. Therefore, the bed capacity increased sharply, greatly relieving the pressure of patient hospitalization. The second challenge was the limited emergency treatment capacity. During the epidemic, many general hospitals undertook the tasks of emergency admission, treating COVID-19 patients, and putting suspected patients in quarantine. However, most hospitals proved inexperienced in reforming medical institutions for segregated diagnosis and treatment, completing the quarantining of confirmed and suspected cases, effectively interrupting transmission routes, and diagnosing and treating the disease. 21 Moreover, the lack of treatment capacity delayed the treatment of patients with other diseases such as tumors or traumatic infections. The third challenge was poor conditions at fever clinics. During the SARS outbreak of 2003, many hospitals set up fever clinics, but some were put on hold for a long time, and their infrastructure could not fulfill the biosecurity requirements of SARS-CoV-2. The COVID-19 epidemic necessitated temporary fever clinic resumption or construction and facility and condition improvements. Moreover, these fever clinics strictly followed the observation and diagnostic protocols during quarantine, which subsequently increased the detection and hospitalization admission time, thereby contributing to extended waiting times.

3. Recommendations

3.1. Capacity building for biosecurity management systems and emergency response mechanisms in hospitals

At the core of the national medical treatment system, hospitals play a major role in the biosecurity defense. In recent years, hospitals have gained remarkable achievements in responding to new infectious disease outbreaks such as SARS, H1N1, Ebola, and COVID-19. 22,23 Therefore, it is of immense importance to clarify the status and role of hospitals in the national biosecurity system. First, it is recommended that future biosecurity laws or implementation regulations should clearly define the functions and roles of hospitals from the national level onward at all levels, to legally define and safeguard the responsibilities of hospitals. Second, it is necessary to call on hospitals at all levels to establish leading biosecurity management groups, define their responsibilities and tasks such as undertaking emergency response to biosecurity emergencies in wartime or enhancing biosecurity work leadership and supervision in hospitals in peace. Third, it is essential to refine and improve emergency plans for different biosecurity emergency scenarios. 22 Special attention should be paid to the following aspects: the establishment of a regional joint prevention and management mechanisms; overall planning of biothreat assessment, surveillance, early warning, emergency and disease treatment; whole-chain link and process of restoration and reconstruction; organization and command, talent, disease treatment, information platform, and material and equipment system coordination. 27 In particular, it is imperative to improve the symptom surveillance sentinel point establishment, such as fever and intestinal clinics in hospitals, integrate the symptom and pathogen surveillance systems, enhance the ability to identify unknown pathogens, and improve the early identification and early warning capabilities of biothreat hospital outposts. 27

3.2. Improve investment and guarantee mechanisms for hospital biosecurity construction

As the epidemic swept through the country, all levels and types of hospitals participated in COVID-19 management nationwide, and nosocomial infections occurred in some hospitals for non-communicable diseases in Wuhan and Beijing. This suggests that general hospitals for non-communicable diseases can encounter biosecurity incidents and face serious risks similar to infectious disease hospitals. Therefore, a biothreat treatment system should be developed at the national level under the unified planning and guidance of the competent authorities, and funding support and specialist training should also be reinforced. First, it is essential to increase investment in specialized hospitals such as those for infectious diseases. Based on the resident urban population proportion, it is necessary to increase the number of hospitals that specialize in infectious diseases and set up biosecurity laboratories to meet the need for medium-scale treatment of infectious diseases. Second, it is important to increase investment in public health and epidemic prevention in general hospitals. A sufficient number of infectious disease facilities and standardized fever clinics should be established per the construction requirements. The negative pressure isolation wards should be increased or modified to fulfill the requirements for accepting and treating patients with respiratory infectious diseases, which are normally used for the general patient hospitalization in periods of peace and quarantine and emergency treatment in periods of war. 3,27 Drawing on the effective practices in the United States of America, bio-control training and treatment wards should be set up in hospitals for ready-to-use purposes. Third, it is necessary to improve the guar-
antee mechanisms for emergency materials. It includes improving the national emergency material reserve systems, optimizing the production capacity guarantee and regional layout of important emergency materials, and unblocking the emergency procurement and supply channels. 28,29 This would allow an ensured emergency material and outfit supply, such as medicines, vaccines, antibodies, masks, protective clothing, disinfectants, and goggles, for ready-to-use availability under critical conditions.

3.3. Proceed with the capacity building of biosecurity incident treatment in general hospitals

The emergency treatment capacity of biosecurity incidents is related to the effectiveness of biosecurity incident treatment, the health of the people, and national security and stability. First, it is necessary to establish and improve the biosecurity incident treatment system. Relying on the medical treatment alliance, and graded diagnosis and treatment, we should establish and improve the classification, stratification, and diversion of biosecurity incident treatment mechanisms. We should unblock the conversion mechanism, both in periods of peace and war. Finally, we should urgently authorize non-public medical institutions and laboratories to rapidly expand their detection and treatment capabilities in periods of war. The application of 5G and artificial intelligence image-assisted technologies may help to carry out remote consultation on major infectious diseases and other biological events. It is vital to improve the training of medical personnel, encourage all medical staff to acquire the knowledge and basic skills related to infectious disease management and biosecurity protection, and emphasize on the importance of training protection knowledge, infectious disease-related skills, and biosecurity among non-infectious and grass-root medical staff with low seniority and professional titles. 30,31 Second, the technical and quality management standards of diagnosis and treatment need to be improved. 26 The intervention measures for infectious disease prevention and control should be strictly implemented, and the strategic pass should be moved up to achieve the “four early” steps (early detection, reporting, quarantine, and treatment). In particular, the treatment of mild cases should be prioritized. This would reduce the mild-to-severe case transition, as well as the treatment of severe cases, thereby reducing the mortality rate. Third, scientific and technological innovation such as developing robot delivery systems and UAV sterilization devices, upgrading medical emergency vehicles, negative-pressure quarantine stretchers and first-aid devices, is extremely necessary. Furthermore, such innovations would accelerate the research and application of novel technologies and treatments, including convalescent plasma treatment and blood purification treatment. It is vital to advance laboratory detection and diagnosis, and to establish on-site rapid detection technologies such as isothermal amplification, mass spectrometry, as well as improved rapid pathogen detection. 27

3.4. Develop overall plans for integrated construction of medical treatment and prevention hospitals and disease-control systems

Disease-control systems and medical institutions are crucial components of the national biosecurity constructions. Through the dynamic integration of and cooperation between these two components, it is possible to ensure population health and develop better biosecurity systems. However, problems such as “stressing the importance of treatment but neglecting prevention” and “separating treatment from prevention” are ubiquitous in the country. The lessons learned from the epidemic are extremely profound. Therefore, greater effort should be invested in integrating medical and preventive forces and forming a pattern of integrated treatment and prevention facility construction. First, it is necessary to further promote disease-control system reforms. 32 The tripartite forces of disease-control institutions, general and specialized hospitals, and grassroot medical and health units should be properly coordinated in order to establish an interdependent “trinity” of disease-control systems characterized by division of labor, cooperation, and interdependence on the strengths of one another. 33 This would further intensify the role and function of hospital disease-control departments. In key and sensitive departments, such as the emergency department, disease-control experts should be assigned and conferred adequate governance authority in terms of rights and responsibilities to enhance the ability of hospitals to deal with biosecurity incidents, such as public health emergencies. Second, improving the emergency response mechanism is vital for integrated treatment and prevention. We recommend the improvement of the effective interaction of scientific research, disease control, and clinical treatment. Moreover, we suggest improving the coordination of research, assessment, decision-making, and prevention and control capabilities for major biosecurity risks. The facilitation of interregional and interinstitutional exchanges, 34 the examination and clarification of institutional responsibilities along with the development of interaction protocols for various types of biosecurity emergencies to facilitate information and communication, timely assistance for investigations, and provision of mutual assistance and support are of pivotal importance. 35,36 In particular, it is of special importance to establish an institutional mechanism for full participation in the organizational command network for public health emergencies in order to ensure timely response and effective outcomes.

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Availability of data and material

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Competing interests

The authors declare no competing interests.

Authors’ contributions

MH and YQS conceived and wrote the manuscript. ZIG, LJF, ZXF, and LYX critically reviewed and revised the manuscript. All authors have read and approved the final manuscript.

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