



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.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Fangcang shelter hospitals: a novel concept for responding to public health emergencies



Simiao Chen*, Zongjiu Zhang*, Juntao Yang, Jian Wang, Xiaohui Zhai, Till Bärnighausen†, Chen Wang†

Fangcang shelter hospitals are a novel public health concept. They were implemented for the first time in China in February, 2020, to tackle the coronavirus disease 2019 (COVID-19) outbreak. The Fangcang shelter hospitals in China were large-scale, temporary hospitals, rapidly built by converting existing public venues, such as stadiums and exhibition centres, into health-care facilities. They served to isolate patients with mild to moderate COVID-19 from their families and communities, while providing medical care, disease monitoring, food, shelter, and social activities. We document the development of Fangcang shelter hospitals during the COVID-19 outbreak in China and explain their three key characteristics (rapid construction, massive scale, and low cost) and five essential functions (isolation, triage, basic medical care, frequent monitoring and rapid referral, and essential living and social engagement). Fangcang shelter hospitals could be powerful components of national responses to the COVID-19 pandemic, as well as future epidemics and public health emergencies.

Introduction

Fangcang shelter hospitals were developed and used for the first time in China to tackle the coronavirus disease 2019 (COVID-19) outbreak.¹ The term Fangcang, which sounds similar to Noah's Ark in Chinese, was borrowed from military field hospitals,^{2,3} but it refers to a novel concept: large, temporary hospitals built by converting public venues, such as stadiums and exhibition centres, into health-care facilities to isolate patients with mild to moderate symptoms of an infectious disease from their families and communities, while providing medical care, disease monitoring, food, shelter, and social activities.

The experience with Fangcang shelter hospitals during the COVID-19 outbreak in China suggests that they could be powerfully employed in future public health emergencies, in particular other epidemics, but also during other events involving illness or injury on a large or rapidly growing scale, such as mass poisonings or natural disasters. The Fangcang shelter hospitals, which can be rapidly established,^{4,5} can provide large numbers of hospital beds and appropriate care for patients who do not have severe

or critical disease.^{5,6} Health workers at Fangcang shelter hospitals can transfer patients to higher-level hospitals for more complex treatment if their conditions worsen.⁶ Fangcang shelter hospitals can also offer emotional and social support to help patients recover and thrive during an otherwise disruptive period in their lives.⁶ In this report, we document the conception and development of Fangcang shelter hospitals during the COVID-19 outbreak in China, describe their key characteristics and essential functions, discuss critical issues for the success of Fangcang shelter hospitals, and consider applications of the concept as part of the COVID-19 public health response in other countries.

Development of Fangcang shelter hospitals in Wuhan

Wuhan, the capital city of Hubei province in China, was the epicentre of the COVID-19 pandemic. As of March 27, 2020, confirmed cases of COVID-19 in Wuhan accounted for more than 60% of all confirmed cases in China.⁷ The surge of infections placed huge pressure

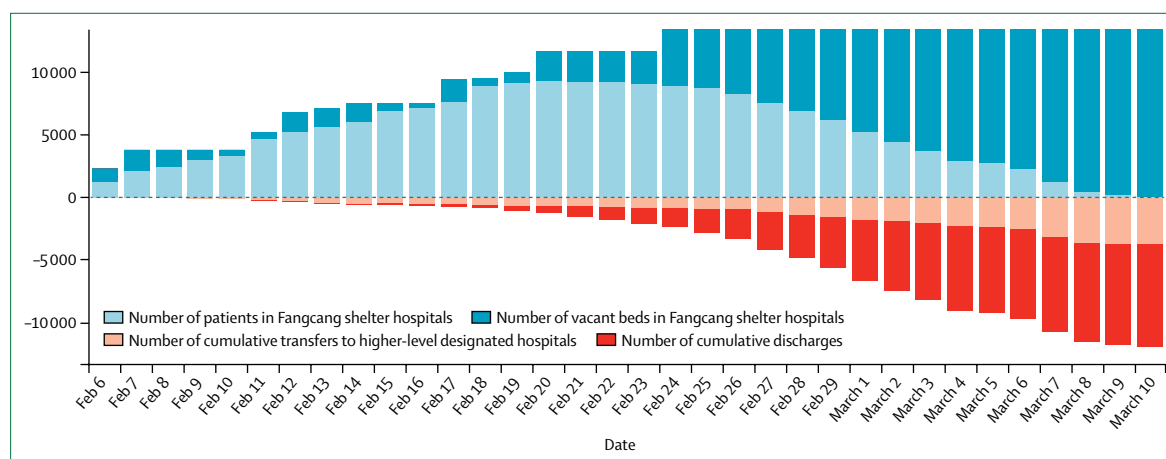


Figure 1: Fangcang shelter hospital patient flows during the coronavirus disease 2019 outbreak in Wuhan, China. All dates are in 2020.

Lancet 2020; 395: 1305–14

Published Online

April 2, 2020

[https://doi.org/10.1016/S0140-6736\(20\)30744-3](https://doi.org/10.1016/S0140-6736(20)30744-3)

50140-6736(20)30744-3

This online publication has been corrected. The corrected version first appeared at [thelancet.com](https://www.thelancet.com) on April 16, 2020

*Co-first authors

†Co-senior authors

Heidelberg Institute of Global Health, Faculty of Medicine and University Hospital, Heidelberg University, Heidelberg, Germany

(S Chen ScD, Prof T Bärnighausen MD); Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China

(S Chen, Prof T Bärnighausen, Prof C Wang MD); National Health Commission of the People's Republic of China, Beijing, China (Z Zhang BS); State Key Laboratory of

Medical Molecular Biology, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China (J Yang PhD); National Center for Medical Service

Administration, Beijing, China (J Wang BS, X Zhai MS); Department of Global Health and Population, Harvard T H Chan School of Public Health, Boston, MA, USA

(Prof T Bärnighausen); National Clinical Research Center for Respiratory Diseases, Beijing, China (Prof C Wang); Department of Pulmonary and Critical Care Medicine, Center of Respiratory Medicine, China-Japan Friendship Hospital, Beijing, China (Prof C Wang); and Chinese Academy of Engineering, Beijing, China (Prof C Wang)

Correspondence to: Prof Chen Wang, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 100730, China

wangchen@pumc.edu.cn

or

Dr Juntao Yang, State Key Laboratory of Medical Molecular Biology, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 100005, China
 yangjt@pumc.edu.cn

on the city's medical system.⁷ At the beginning of February, 2020, Wuhan had no beds available for COVID-19 patients in the hospitals designated for treating the virus.⁸ Thousands of patients with mild to moderate COVID-19 had to be sent home for isolation and observation. With a shortage of hospital beds, Wuhan needed an approach to rapidly and massively scale its capacity to isolate and care for patients with mild to moderate COVID-19. As the outbreak in Wuhan reached its most severe point, with thousands of new infections per day, the city opened three Fangcang shelter hospitals on Feb 5, 2020, by converting exhibition centres and stadiums. Over the following weeks, Wuhan opened an additional 13 Fangcang shelter hospitals.⁹ Figure 1 shows the progression of bed capacity and occupancy of the Fangcang shelter hospitals over time. As the epidemic in

Wuhan subsided and bed occupancy moved towards zero, the Fangcang shelter hospitals were successively suspended. The first hospital closed on March 1, 2020; by March 10, all Fangcang shelter hospitals had been suspended.^{10,11}

Home isolation is an important alternative to hospital isolation, which requires behaviour change but no additional infrastructure investment. Chinese policy makers decided against home isolation of patients with mild to moderate COVID-19 for a number of important reasons.^{12,13} First, home isolation puts patients' family members at risk. Early epidemiological evidence in China showed that more than half of all patients with COVID-19 had at least one family member with the disease, and 75–80% of all clustered infections were within families, suggesting high rates of intrafamily

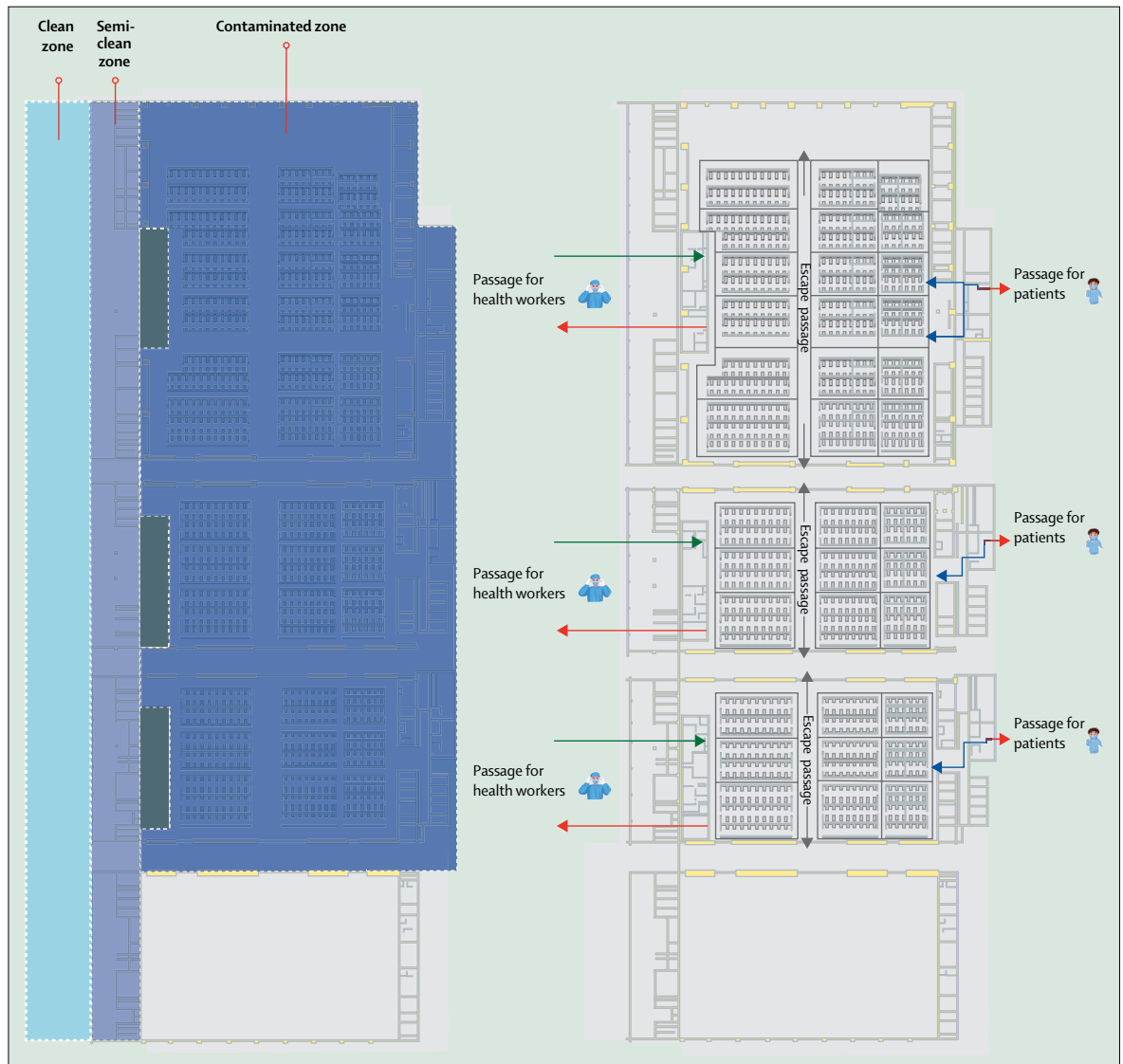


Figure 2: Zones and passages in a Fangcang shelter hospital in Wuhan, China
 Adapted with permission of ThePaper.²⁹

transmission.^{14–18} Second, patients can find home isolation psychologically taxing, because they know that they are putting those they care about most at risk of contracting the disease.^{19,20} Third, home isolation is unlikely to be fully effective because it cannot be strictly enforced. Patients might break with the mandated behaviour to stay at home and go outside for errands, entertainment, or exercise. Lastly, it is difficult to organise medical care, frequent monitoring of disease progression, and timely referral to hospital care for thousands of patients in home isolation.²¹ COVID-19 can deteriorate from mild or moderate to severe illness, requiring rapid referral to hospital care.^{16–18} In home isolation in Wuhan, before the introduction of the Fangcang shelter hospitals, the time from onset of severe symptoms to admission to a tertiary hospital for intensive care was up to 10 days.^{8,22} The Fangcang shelter hospitals substantially reduced these delays.

Hospital isolation of the growing numbers of COVID-19 patients in Wuhan was not feasible, and home isolation was not desirable. China thus needed a novel approach to control the COVID-19 outbreak in Wuhan. In response, Chinese officials and experts developed the Fangcang shelter hospital: large health-care facilities that were built overnight and provided isolation, triage, medical care, monitoring and referral, shelter, and social engagement. The hospitals were built in existing public venues by installing beds, sheltered space, and the three zones and two passages (*san qu liang tong dao*) of hospital isolation wards.^{23–28} Figure 2 shows one of the Fangcang shelter hospitals in Wuhan with three zones—a contaminated zone where patients live, a semi-clean zone where health

workers put on and take off their protective suits, and a clean zone where supplies are received—and two passages, one for patients and the other for health workers. Although Fangcang shelter hospitals have some historic precedents, such as makeshift hospitals, emergency field hospitals, emergency shelters, and hospital isolation wards,^{30–32} they have three distinct characteristics and five functions that set them apart from facilities that have previously been used for the control of public health emergencies.

Three key characteristics of Fangcang shelter hospitals

Fangcang shelter hospitals have three characteristics that make them particularly well suited to address public health emergencies, such as the COVID-19 outbreak in Wuhan (figure 3).³³ The first characteristic is rapid construction. Fangcang shelter hospitals can be built quickly because they are based inside existing physical infrastructure. The conversion process, in which buildings that served other purposes (eg, sports venues or exhibition centres) were turned into hospitals, was completed in 29 hours for the first three Fangcang shelter hospitals in Wuhan, providing 4000 beds.⁴⁵ This process involved some interior redesign of spaces and purchasing and installing beds, medical devices, and supplies to support care, monitoring, and sheltered living.

The second characteristic is massive scale. Fangcang shelter hospitals leverage large-scale public venues, which, once they have been converted to serve hospital functions, result in a large increase in health-care capacity (figure 1). The 16 Fangcang shelter hospitals that China

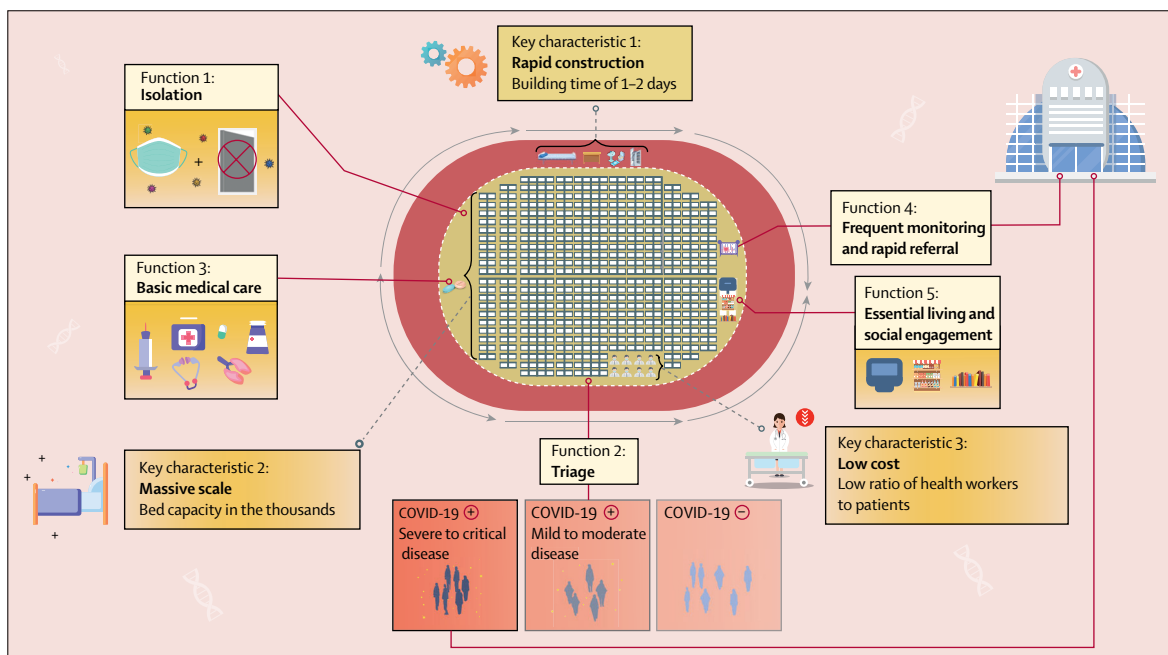


Figure 3: Key characteristics and essential functions of Fangcang shelter hospitals
 COVID-19=coronavirus disease 2019.

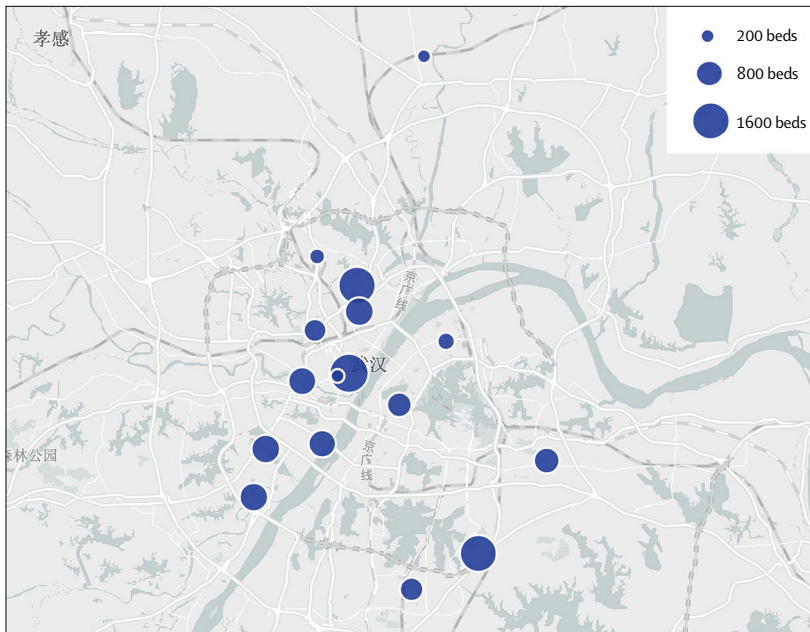


Figure 4: Fangcang shelter hospital locations and capacities during the coronavirus disease 2019 outbreak in Wuhan, China

Circle size is proportional to the number of hospital beds in each Fangcang shelter hospital.

built over a period of 3 weeks contained 13 000 hospital beds (figure 4). By March 10, 2020, the 16 hospitals had provided care to about 12 000 patients.³⁴ In caring for and sheltering such a large number of patients who would otherwise have been confined to their homes, these shelter hospitals effectively supported China's COVID-19 policy of leaving no patient unattended or untreated.³⁵

The third characteristic is the low cost of building and running Fangcang shelter hospitals. Investment costs are low because converting public venues into health-care facilities avoids costly construction of new physical infrastructure. Equally, once the epidemic has subsided, the structures can be returned to their original purposes, avoiding long-term, inefficient use of space, which is a particularly important consideration in a densely populated city. Running costs are low because Fangcang shelter hospitals require fewer doctors and nurses than traditional hospitals.³⁶ The low health worker-to-patient ratio is for two reasons: first, all patients in the hospital share the same primary admission diagnosis, reducing the complexity of care, and second, all patients have only mild to moderate disease.^{9,37} By isolating and treating only mild to moderate cases, Fangcang shelter hospitals in Wuhan freed up the scarce medical infrastructure of higher-level hospitals, such as the inpatient units providing respiratory support and intensive care, for patients with severe to critical COVID-19 and other patients requiring critical or complex care. More than 90% of severe cases in Hubei province were in Wuhan,³⁸ and the bed vacancy rate in the traditional hospitals

designated for the care of patients with COVID-19 increased from 4% on Feb 4, 2020 (before the first Fangcang shelter hospitals had opened) to 16% on Feb 22, when 16 Fangcang shelter hospitals had started admitting patients.³⁸ The Fangcang shelter hospitals improved the distribution of patients with COVID-19 according to the severity of their symptoms, increasing the overall efficiency of care.

Five essential functions of Fangcang shelter hospitals

Figure 3 summarises the functions of Fangcang shelter hospitals. The first essential function is isolation. Before the construction of the hospitals, thousands of patients with mild to moderate COVID-19 in Wuhan had to be sent home for isolation. Patients with mild to moderate symptoms are generally more active than the severely ill and thus in greater contact with others, increasing the possibility of transmission and placing family and community members at risk.³⁹ The Fangcang shelter hospitals isolated COVID-19 patients more effectively from their communities than home isolation.

The second essential function is triage. The Fangcang shelter hospitals inserted an additional level of care into the Chinese health system and thus served a strategic triage function for patients with COVID-19. Patients with mild to moderate COVID-19 who met additional admission criteria (table)^{6,46} were isolated and treated in the Fangcang shelter hospitals, whereas patients with severe to critical COVID-19 received care in traditional hospitals. This strategic triage function released pressure on traditional hospitals, and as a result, the Fangcang shelter hospitals are likely to have boosted both the efficiency and effectiveness of the COVID-19 response in China. The Fangcang shelter hospitals allowed the health system in Wuhan to prioritise those who had severe to critical disease for care in traditional hospitals (about 20% of patients with COVID-19), while ensuring appropriate care for those who experienced mild to moderate disease (about 80% of patients with COVID-19).^{46,33}

As a third essential function, Fangcang shelter hospitals provide basic medical care, including antiviral, antipyretic and antibiotic medication; oxygen supplementation and intravenous fluids; and mental health counselling.⁶ Two case reports illustrating typical medical histories during a stay at a Fangcang shelter hospital are shown in the panel. To support medical care, a few days after the opening of the first Fangcang shelter hospitals, health workers in Wuhan had access to electronic information systems, supported by cloud platforms and connected with higher-level hospitals, for record keeping, data transfer, and monitoring of quality of care and outcomes.⁴⁶

The fourth essential function is frequent monitoring and rapid referral. The Fangcang shelter hospitals in Wuhan were integrated into the overall health systems via simple pathways of referral and transfer.⁶ The health workers in the Fangcang shelter hospitals monitored

	Reason for criterion	Alternative care pathway if criterion is not met
Positive COVID-19 test with mild signs or symptoms (mild clinical symptoms, imaging shows no signs of pneumonia) to moderate signs or symptoms (fever, respiratory tract symptoms, imaging shows pneumonia)	The primary purpose of the Fangcang shelter hospitals is to greatly expand capacity to care for COVID-19 patients with mild to moderate signs or symptoms	Patients with severe signs or symptoms are referred to higher-level hospitals; suspected cases are referred to quarantine locations with continued community screening for COVID-19
Ability to walk and live independently	Fangcang shelter hospitals cannot provide intensive care for patients who cannot take care of themselves	Referred to higher-level hospitals
Absence of severe chronic diseases, including hypertension, diabetes, coronary heart disease, malignancy, structural lung disease, pulmonary heart disease, and immunosuppression	Early evidence suggests that patients with underlying health conditions, such as hypertension, diabetes, and cardiovascular disease, are more likely than patients without these comorbidities to develop severe COVID-19 ^{33,40,41}	Referred to higher-level hospitals
No history of mental health conditions	Fangcang shelter hospitals do not have the capacity to treat psychiatric diseases; in addition, early evidence suggests that patients with some mental health conditions, such as anorexia nervosa, are more likely to develop severe COVID-19 ⁴⁰	Referred to higher-level hospitals
<65 years old	Early evidence suggests that older patients are at considerably increased risk of developing severe COVID-19 ^{33,40,41}	Referred to higher-level hospitals
Negative influenza test	Admission to Fangcang shelter hospitals should not increase the risk of influenza co-infection ⁴²	Referred to higher-level hospitals
SpO ₂ >93% and breathing rate <30 beats per min in resting state	Oxygen saturation and breathing rate are important physiological parameters of the respiratory and circulatory system, and are used to gauge the severity of COVID-19; ^{43,44} early evidence suggests that patients with dyspnoea and hypoxia (SpO ₂ <93%) should receive supplemental oxygen and be admitted to an isolation ward ⁴⁵	Referred to higher-level hospitals

These criteria were applied during the COVID-19 outbreak in Wuhan, China in February to March, 2020.^{6,42} COVID-19=coronavirus disease 2019. SpO₂=blood oxygen saturation.

Table: Fangcang shelter hospital admission criteria

the progression of disease by measuring respiration rate, temperature, oxygen saturation, and blood pressure multiple times per day.⁶ For more specialised monitoring, the health workers in the Fangcang shelter hospitals could use imaging and laboratory services, which were available in mobile health units outside the hospitals. If patients met any of the following clinical criteria, they were quickly transferred to designated higher-level hospitals: respiration rate of 30 beats per min or higher; blood oxygen saturation of 93% or lower; a partial pressure of arterial oxygen to fraction of inspired oxygen ratio of 300 mm Hg or less; lung imaging showing a greater than 50% progression of lesions within 24–48 h; or the identification or development of severe chronic diseases, including hypertension, diabetes, coronary heart disease, cancer, structural lung disease, pulmonary heart disease, or immunosuppression.⁶ Health workers also provided a range of specific tests, such as nucleic acid tests and CT scans, to ensure that worsening health status was quickly identified and confirmed in particular cases (panel).⁶ As of Feb 29, 2020—the day before the first Fangcang shelter hospital was suspended—the cumulative number of patients who were transferred to higher-level hospitals was 13% of the total patients admitted to the Fangcang shelter hospitals (figure 1). After Feb 29, this percentage increased because all patients who had not been discharged before the Fangcang shelter hospitals closed were routinely referred to higher-level hospitals. Overall, Fangcang shelter hospitals are likely to have substantially reduced the time from the

Panel: Case reports of patients in Fangcang shelter hospitals

Male patient, 37 years old

On Jan 29, 2020, the patient developed a dry cough without fever and a chest CT scan showed pneumonia affecting the left lung. On Feb 19, the patient tested positive for coronavirus disease 2019 (COVID-19) in a nucleic acid test. The patient was admitted to a Fangcang shelter hospital in Wuhan on Feb 20. After admission, his temperature was normal, with occasional cough but no sputum. He was given oral umifenovir and Chinese traditional medicine (*qingfei paidutang*), which has shown promise in treating COVID-19 patients according to the National Administration of Traditional Chinese Medicine.⁴⁷ The patient's cough lessened. He tested negative for COVID-19 in nucleic acid tests on Feb 25, and Feb 27, and met the other criteria for discharge by Feb 27. The patient was discharged on Feb 29.

Female patient, 68 years old

On Jan 28, 2020, the patient developed a dry cough without fever and a chest CT scan on the same day showed ground-glass opacity. She tested positive for COVID-19 in a nucleic acid test on Feb 14. She was admitted to a Fangcang shelter hospital in Wuhan on Feb 17, even though she did not meet the age admission criterion (table), because she had relatives who were patients in the same Fangcang shelter hospital. The patient's temperature remained normal after admission, with continued cough, no sputum, and no dyspnoea. In the Fangcang shelter hospital, the patient received umifenovir and the Chinese traditional medicine *qingfei paidutang* orally. In nucleic acid tests, she tested negative for COVID-19 on Feb 22, but she tested positive on Feb 24. A CT scan on Feb 24 showed intensifying ground-glass opacity and consolidation in both lungs. She was transferred to a traditional hospital designated for more intensive COVID-19 care on Feb 28 to continue treatment.

onset of severe symptoms to admission to a higher-level hospital, compared to the alternative of home isolation.^{8,22} The health workers in the Fangcang shelter hospitals

discharged patients if they met all of the following criteria: normal body temperature for >3 days, significant improvement of respiratory symptoms, lung imaging showing obvious absorption of inflammation, and negative nucleic acid tests results for COVID-19 at two consecutive times with a sampling interval of at least 1 day.⁶ Before discharge from the Fangcang shelter hospitals, patients showered, put on freshly washed clothes, and were sprayed with disinfectant. After discharge, patients spent a further 2 weeks in dedicated quarantine area in Wuhan, such as hotels, before they returned to their homes and families.

The fifth essential function that Fangcang shelter hospitals provide is essential living and social engagement. Functions of essential living, including shelter, accommodation, food, sanitation, and hygiene, are of course necessary to care for the large numbers of people in the hospitals. In addition, social engagement was intended to both promote patients' recovery and alleviate the anxiety that a COVID-19 diagnosis and isolation could cause. China conceived the Fangcang shelter hospitals as a community of patients, in which patients are isolated from the COVID-19-negative population but support each other and engage in social activities. Health workers provided emotional support in addition to medical care;^{5,8,48} community activities included eating together, watching television, dancing, reading, and celebrating birthdays.^{48,49}

Critical considerations for the running of Fangcang shelter hospitals

As part of an epidemic control strategy, Fangcang shelter hospitals require several supportive strategies and solutions, including a human resources strategy, a communication and public engagement strategy, a governance structure, and measures to prevent nosocomial infections and provide patients with a degree of privacy.

Human resources

As mentioned previously, Fangcang shelter hospitals can increase the efficiency of the COVID-19 response, because they release patients who do not require intensive or complex care from the more highly staffed traditional hospitals to the less highly staffed shelter hospitals. These efficiency gains are likely to lessen health worker shortfalls in a given epidemic situation, but additional health workers will probably be required to staff the Fangcang shelter hospital beds that are needed for an effective response to a rapidly growing epidemic. China mobilised health workers from across the country for the COVID-19 response in Wuhan, to the extent that the majority of health workers in the Fangcang shelter hospitals came from outside of Hubei province.⁶ All of these health workers were either qualified as medical doctors or nurses.⁶ Before being deployed in Fangcang shelter hospitals, these medical professionals received specific education on the natural course of COVID-19 and the

current evidence and best practices regarding COVID-19 diagnosis, treatment, prevention of co-infection, and protection from COVID-19 transmission. Health workers and clerical staff were also specifically trained in the electronic patient record system, medication supply management, and discharge and referral management of the Fangcang shelter hospitals.⁶

Communication and public engagement

China realised early on in the COVID-19 response that a strong communication and public engagement strategy would be key to ensuring that the population knew about Fangcang shelter hospitals and supported their use. Chinese government officials made several public announcements and held press conferences to inform the public about Fangcang shelter hospitals.^{5,50} In addition, government officials and health workers gave interviews explaining the purpose and functions of the hospitals.^{9,51-53} Shortly after the Fangcang shelter hospitals began operating, patients and health workers started publishing accounts of their experiences in the hospitals in both traditional and social media,^{48,49,54,55} complementing news items and feature articles on the hospitals.^{5,9,42,56-58}

Governance

To coordinate the COVID-19 response, the Chinese Central Government convened a Central Leadership Group for Epidemic Response, led by the premier, and a subordinated Central Leadership Group for Hubei Province, led by the vice premier, who relocated to Wuhan to guide the control initiatives during the epidemic.^{16,59,60} China also established the Joint Prevention and Control Mechanism of the State Council to coordinate epidemic control initiatives across government sectors. The National Health Commission led the Joint Prevention and Control Mechanism and convened multiple working groups for the national COVID-19 response, including for scientific research, clinical treatment, and medical supplies.^{16,35,61} The Central Leadership Group for Hubei Province decided to build Fangcang shelter hospitals and the National Health Commission guided their design and implementation. Finally, the Wuhan Municipal Headquarters for COVID-19 Prevention and Control built the Fangcang shelter hospitals and managed their day-to-day operations, including clinical care, sourcing and supply of health-care products and food, utilities, and security.

Prevention of nosocomial infection

To reduce the risk of nosocomial infections in Fangcang shelter hospitals—both among patients and between patients and health workers—all patients were required to test positive for COVID-19 and negative for influenza before admission (table). In the hospitals, patients received one to two protective masks per day, which they were required to wear to lower the risk of transmission and acquisition of infectious respiratory diseases. Further measures to reduce nosocomial infections included

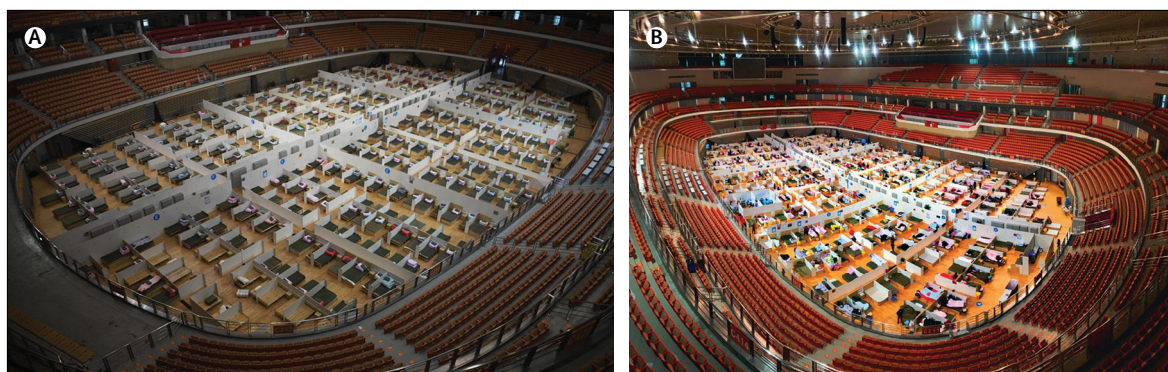


Figure 5: A Fangcang shelter hospital during the coronavirus disease 2019 outbreak in Wuhan, China

The hospital is shown before (A) and after (B) admission of patients. The images are reproduced with permission of Min Cheng, Xinhua News (A), and Xingxin Zhu, China Daily (B).

intensive training for health workers and standard operating procedures and protocols guiding the use of protective equipment and passage across the contaminated, semi-clean, and clean zones.⁶ These measures ensured that the risk of nosocomial infections in Fangcang shelter hospitals was not higher than in traditional hospitals.

Privacy

To ensure some degree of privacy similar to that provided in traditional hospitals, Fangcang shelter hospitals contained partitions that separated bed units into spaces resembling hospital rooms and wards (figure 5). In addition, men and women lived in different areas. For example, in one of the Fangcang shelter hospitals, women lived on the first floor and men lived on the second floor.

Comparison with makeshift and emergency field hospitals

Fangcang shelter hospitals may seem similar to the makeshift and emergency field hospitals used during previous epidemics in other countries,^{30,32,62–64} for example, in the USA during the 1918–19 influenza pandemic,⁶⁵ or in African countries during the 2014–15 Ebola epidemic.^{66,67} However, they differ in several important ways. First, the Fangcang shelter hospitals in China were established to isolate the patients who were most likely to transmit the infection because they had only mild to moderate COVID-19 and were thus likely to be active in their daily lives and in contact with family and community members. Second, the Fangcang shelter hospitals served an important triage function, separating patients by severity of symptoms,^{64,42} which was not a focus of previous makeshift and emergency field hospitals.^{62,66} Third, Fangcang shelter hospitals became a national standard of care, rather than a temporary, emergency measure to bridge a gap until improved capacity for mass treatment became available.^{64,41} This standard of care was supported by rigorous quality control and improvement routines, designation of the hospitals as infectious disease zones, and through public

health infrastructure standards for air conditioning, ventilation systems, and bathroom facilities. Fourth, the Fangcang shelter hospitals provided more hospital beds within a shorter period of time than previous makeshift and emergency field hospitals.⁶² Finally, in contrast to makeshift and emergency field hospitals, Fangcang shelter hospitals were not only health-care facilities, but also served as social spaces, providing essential living, emotional support, and social engagement for the large numbers of patients that lived in isolation from their families and communities. In a sense, Fangcang shelter hospitals served as communities of patients with mild to moderate COVID-19.

Fangcang shelter hospitals as part of the COVID-19 response in other countries

As the COVID-19 pandemic spreads globally, countries other than China are experiencing shortages of beds in traditional hospitals caring for the rapidly growing numbers of patients with the disease.^{68,69} For example, in Italy, local authorities in some regions have asked hospital managers to free up intensive care unit beds for patients with COVID-19 and to reduce their elective surgeries by 70%.⁷⁰ By March 10, 2020, more than 80% of the hospital beds in the Italian region of Lombardy were occupied by patients with COVID-19.^{69,71}

China has started to support other countries, such as Italy, Iran, and Serbia, in formulating policies to control the COVID-19 pandemic and conceiving and constructing Fangcang shelter hospitals for their national contexts. As part of this international cooperation, China has translated all policies, management manuals, and clinical guidelines related to Fangcang shelter hospitals into the languages of other countries facing rapidly growing COVID-19 outbreaks. China has also sent experts with direct experience in constructing and running Fangcang shelter hospitals to other countries to provide consultancy services to national and local governments.^{72,73}

Similar to China, Serbia is building Fangcang shelter hospitals by converting public venues into health-care

facilities to isolate and treat patients with mild to moderate COVID-19.^{74,75} Iran, the USA, the UK, and Spain are implementing measures that are similar to Fangcang shelter hospitals.^{76–80} It is likely that many other countries, including in sub-Saharan Africa and Asia, will also need to adopt such measures to ensure sufficient capacity to both effectively isolate and care for the large numbers of people who will experience mild to moderate COVID-19.

Conclusions

During the COVID-19 outbreak in Wuhan, China, Fangcang shelter hospitals isolated thousands of patients, provided high-quality medical treatment and care, and fulfilled an important triage function. Early descriptive evidence suggests that the Fangcang shelter hospitals were a major reason for the successful COVID-19 control in China. The number of confirmed cases in Wuhan steadily declined from Feb 18, 2020, 12 days after the first Fangcang shelter hospitals started admitting patients.⁷ As the number of new infections continued to decline, China suspended all Fangcang shelter hospitals.³⁴ Future research should establish the causal impact of Fangcang shelter hospitals on COVID-19 incidence and population health outcomes.

Other countries facing the COVID-19 pandemic should consider using Fangcang shelter hospitals as part of their public health response. Future design and construction of large public venues (eg, stadiums, convention centres, exhibition centres, gymnasiums, factories, and warehouses) should integrate features facilitating the conversion of these infrastructures to Fangcang shelter hospitals, such as interior equipment that can be rapidly removed, entrances that are large enough for hospital beds, and ventilation systems that reduce the risk of cross-infection. By embracing Fangcang shelter hospitals, many countries and communities worldwide could boost their response to the current COVID-19 pandemic as well as future epidemics and disasters.

Contributors

CW conceptualised and designed the Fangcang shelter hospitals in Wuhan, China, during the COVID-19 outbreak and initiated and coordinated this study. He identified key indicators for operating and evaluating Fangcang shelter hospitals and acquired the data and information for this study. SC and TB conceived and conducted the analyses, processed and visualised the data, and reviewed the literature. JY acquired data and key information, and contributed to literature review and data visualisation. ZZ contributed to the design and implementation of Fangcang shelter hospitals, and acquired key information. JW and XZ participated in building and running Fangcang shelter hospitals, and acquired key information. SC, CW, and TB conceived this article; SC wrote the first draft; CW and TB critically revised the article. All authors approved the final version.

Declaration of interests

We declare no competing interests.

Acknowledgments

We thank the health workers and all other people working in and supporting the Fangcang shelter hospitals in Wuhan, China. TB was supported by the Alexander von Humboldt Foundation, through the Alexander von Humboldt Professor award.

References

- Chen S, Yang J, Yang W, Wang C, Barnighausen T. COVID-19 control in China during mass population movements at New Year. *Lancet* 2020; **395**: 764–66.
- Yue W, Chen K, Wang K, Zhang S, Tao L. Construction of mobile field hospitals under the condition of informationisation (in Chinese). *Hosp Adm J Chin People's Liberation Army* 2017; **24**: 962–64.
- Wang B, Cheng Z. Development and prospects of mobile field hospitals (in Chinese). *Chin Med Equip J* 2011; **33**: 92–96.
- Xinhua News. Racing to build Fangcang shelter hospitals (in Chinese). Feb 6, 2020. http://www.xinhuanet.com/local/2020-02/06/c_1125540266.htm (accessed Feb 9, 2020).
- Wuhan Municipal Health Commission. Fangcang shelter hospitals have helped in achieving “leaving no patients untreated” (in Chinese). Feb 24, 2020. <http://wjw.wuhan.gov.cn/front/web/showDetail/2020022409772> (accessed Feb 24, 2020).
- The National Health Commission of the People's Republic of China. Manual for working in Fangcang shelter hospitals (3rd edn; in Chinese). Feb 22, 2020. <https://mp.weixin.qq.com/s/va9vs4HuP8wRQM5fALQcrg> (accessed Feb 24, 2020).
- National Health Commission of the People's Republic of China. Updates on the epidemic (in Chinese). March 27, 2020. <http://www.nhc.gov.cn/xcs/yqtb/202003/bf66696029ba420098164607240074f8.shtml> (accessed March 28, 2020).
- Xinhua News. Noah's Ark: the story of Fangcang shelter hospitals (in Chinese). Feb 19, 2020. http://www.xinhuanet.com/2020-02/19/c_1125598560.htm (accessed Feb 24, 2020).
- The State Council of the People's Republic of China. The State Council Information Office holds a press conference on the progress of the epidemic prevention and control, and medical rescue works guided by the Central Leadership Group (in Chinese). Feb 28, 2020. http://www.gov.cn/xinwen/2020-02/28/content_5484713.htm (accessed March 27, 2020).
- Changjiang Daily. Wuhan's Qiaokou Wuti Fangcang shelter hospital becomes the first closed Fangcang shelter hospital (in Chinese). March 1, 2020. <https://mp.weixin.qq.com/s/5yEF1YADZ9v1ClA0Dj703w> (accessed March 1, 2020).
- People's Daily. Patients and medical workers bid farewell before final Fangcang makeshift hospital shuts down. March 14, 2020. <http://en.people.cn/n3/2020/0314/c98649-9668313.html> (accessed March 15, 2020).
- The State Council of the People's Republic of China. New hospitals hailed for role in epidemic control. Feb 10, 2020. http://english.www.gov.cn/news/topnews/202002/10/content_WS5e40ae07c6d0a585c76cae21.html (accessed March 13, 2020).
- The State Council of the People's Republic of China. Vice-premier stresses leaving no coronavirus patients unattended. Feb 10, 2020. http://english.www.gov.cn/statecouncil/sunchunlan/202002/10/content_WS5e408b62c6d0a585c76cad5a.html (accessed March 13, 2020).
- Tian S, Hu N, Lou J, et al. Characteristics of COVID-19 infection in Beijing. *J Infect* 2020; published online Feb 27. DOI:10.1016/j.jinf.2020.02.018.
- Special Expert Group for Control of the Epidemic of Novel Coronavirus Pneumonia of the Chinese Preventive Medicine Association. An update on the epidemiological characteristics of novel coronavirus pneumonia (COVID-19) (in Chinese). *Zhonghua Liu Xing Bing Xue Za Zhi* 2020; **41**: 139–44.
- WHO. Report of the WHO-China Joint Mission on coronavirus disease 2019 (COVID-19). Feb 28, 2020. <https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf> (accessed March 20, 2020).
- McNeil Jr DG. Inside China's all-out war on the coronavirus. March 9, 2020. <https://www.nytimes.com/2020/03/04/health/coronavirus-china-aylward.html> (accessed March 1, 2020).
- Maddow R. How a country serious about coronavirus does testing and quarantine. March 13, 2020. <https://www.msnbc.com/rachel-maddow/watch/how-a-country-serious-about-coronavirus-does-testing-and-quarantine-80595013902> (accessed March 16, 2020).
- BBC News. Coronavirus: health minister Nadine Dorries tests positive. March 11, 2020. <https://www.bbc.com/news/uk-51827356> (accessed March 13, 2020).

- 20 Reeder D. I love you, but I don't want to get you sick. March 14, 2020. <https://psiloveyou.xyz/i-love-you-but-i-dont-want-to-get-you-sick-de88433c85d7> (accessed March 16, 2020).
- 21 Farzan AN. 'Italy has abandoned us': people are being trapped at home with their loved ones' bodies amid coronavirus lockdown. March 12, 2020. <https://www.washingtonpost.com/nation/2020/03/12/coronavirus-bodies-italy-quarantine/> (accessed March 13, 2020).
- 22 Xinhua News. The number of people visiting fever clinic in Wuhan city can be as high as over 15 000 per day (in Chinese). Jan 28, 2020. http://www.xinhuanet.com/2020-01/28/c_1125506630.htm (accessed Feb 9, 2020).
- 23 National Health and Family Planning Commission. Regulation for prevention and control of healthcare associated infection of airborne transmission disease in healthcare facilities. Dec 12, 2016. <http://www.nhc.gov.cn/ewebeditor/uploadfile/2017/01/20170119150530360.pdf> (accessed March 16, 2020).
- 24 Yen M-Y, Lin YE, Su I-J, et al. Using an integrated infection control strategy during outbreak control to minimize nosocomial infection of severe acute respiratory syndrome among healthcare workers. *J Hosp Infect* 2006; **62**: 195–99.
- 25 Fung CP, Hsieh TL, Tan KH, et al. Rapid creation of a temporary isolation ward for patients with severe acute respiratory syndrome in Taiwan. *Infect Control Hosp Epidemiol* 2004; **25**: 1026–32.
- 26 Bannister B, Puro V, Fusco FM, Heptonstall J, Ippolito G, Group EW. Framework for the design and operation of high-level isolation units: consensus of the European Network of Infectious Diseases. *Lancet Infect Dis* 2009; **9**: 45–56.
- 27 Lateef F. Hospital design for better infection control. *J Emerg Trauma Shock* 2009; **2**: 175–79.
- 28 Bataille J, Brouqui P. Building an intelligent hospital to fight contagion. *Clin Infect Dis* 2017; **65** (suppl 1): S4–11.
- 29 ThePaper. Strategy of Fangcang shelter hospitals (in Chinese). March 12, 2020. <https://h5.thepaper.cn/html/zt/2020/03/cabin/index.html> (accessed March 15, 2020).
- 30 Pan American Health Organization. WHO-PAHO Guidelines for the use of foreign field hospitals in the aftermath of sudden-impact disasters. 2003. <https://www.who.int/hac/techguidance/pht/FieldHospitalsFolletto.pdf> (accessed March 10, 2020).
- 31 Barbisch D, Koenig KL, Shih F-Y. Is there a case for quarantine? Perspectives from SARS to Ebola. *Disaster Med Public Health Prep* 2015; **9**: 547–53.
- 32 Hepburn NC, Brooks TJ. An outbreak of chickenpox in a military field hospital—the implications for biological warfare. *J R Soc Med* 1991; **84**: 721–22.
- 33 Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of coronavirus disease 2019 (COVID-19) in China (in Chinese). *Zhonghua Liu Xing Bing Xue Za Zhi* 2020; **41**: 145–51.
- 34 China News. All Fangcang shelter hospitals are suspended: achieving zero cross-infection and zero death; bolstering Wuhan's fight against COVID-19 (in Chinese). March 10, 2020. <http://www.chinanews.com/gn/2020/03-10/9120429.shtml> (accessed March 15, 2020).
- 35 The State Council of the People's Republic of China. The Joint Prevention and Control Mechanism of the State Council launch announcement on further shouldering responsibilities and implementing prevention and control strategies (in Chinese). Feb 7, 2020. http://www.gov.cn/guowuyuan/2020-02/07/content_5475951.htm (accessed Feb 24, 2020).
- 36 China Daily. Medical teams sent to Wuhan play key role. Feb 21, 2020. <http://epaper.chinadaily.com.cn/a/202002/21/WS5e4f0f6ca310a2fabb7a256f.html> (accessed March 15, 2020).
- 37 National Health Commission of the People's Republic of China. Standards for healthcare organizations (in Chinese). 2017. <http://www.nhc.gov.cn/ewebeditor/uploadfile/2017/06/20170614162520548.docx> (accessed Feb 24, 2020).
- 38 ThePaper. Data from Wuhan Municipal Health Commission: the hospital bed empty bed rate exceeds 16% as of yesterday (in Chinese). Feb 23, 2020. https://www.thepaper.cn/newsDetail_forward_6103833 (accessed Feb 24, 2020).
- 39 Chan JF-W, Yuan S, Kok K-H, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet* 2020; **395**: 514–23.
- 40 Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China: *JAMA* 2020; published online Feb 7. DOI:10.1001/jama.2020.1585.
- 41 Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet* 2020; **395**: 507–13.
- 42 China Daily. Wuchang Fangcang shelter hospital has started to admit COVID-19 patients with mild symptoms (in Chinese). Feb 6, 2020. <https://cn.chinadaily.com.cn/a/202002/06/WS5e3b8e56a3107bb6b579d8ca.html> (accessed Feb 24, 2020).
- 43 Silverstein WK, Stroud L, Cleghorn GE, Leis JA. First imported case of 2019 novel coronavirus in Canada, presenting as mild pneumonia. *Lancet* 2020; **395**: 734.
- 44 Bastola A, Sah R, Rodriguez-Morales AJ, et al. The first 2019 novel coronavirus case in Nepal. *Lancet Infect Dis* 2020; **20**: 279–80.
- 45 Zhang J, Zhou L, Yang Y, Peng W, Wang W, Chen X. Therapeutic and triage strategies for 2019 novel coronavirus disease in fever clinics. *Lancet Respir Med* 2020; **8**: e11–12.
- 46 Yao G, Zhang X, Wang H, Li J, Tian J, Wang L. Practice and thinking of the informationized cabin hospitals during the novel coronavirus pneumonia period (in Chinese). *Chin J Hosp Adm* 2020; published online Feb 23. DOI:10.3760/cma.j.cn112225-20200218-00200.
- 47 National Administration of Traditional Chinese Medicine. People's Daily reports "qing fei pai du tang": Chinese traditional medicine boosts power in fighting the epidemic (in Chinese). March 12, 2020. <http://www.satcm.gov.cn/hudongjiaoliu/guanfangweixin/2020-03-12/13836.html> (accessed March 12, 2020).
- 48 Beijing Daily. A patient from Fangcang shelter hospital has recorded her life in Fangcang (in Chinese). Feb 23, 2020. <http://www.bjd.com.cn/a/202002/23/WS5e526c63e4b05998c6eb7747.html> (accessed Feb 24, 2020).
- 49 China News. Wuhan's coronavirus patients dance away pains in makeshift hospital. Feb 11, 2020. <http://www.ecns.cn/news/society/2020-02-11/detail-iftzmtcih6521787.shtml> (accessed Feb 24, 2020).
- 50 National Health Commission of the People's Republic of China. Wuhan plans to build 19 additional Fangcang shelter hospitals (in Chinese). Feb 22, 2020. <http://www.nhc.gov.cn/xcs/yqfkdt/202002/fe75c7e6cf104026a0a24fca0da38593.shtml> (accessed Feb 22, 2020).
- 51 China News. Director of the National Health Commission of China Xiaowei Ma: Fangcang shelter hospitals has achieved zero infections, zero deaths, and zero readmissions (in Chinese). Feb 28, 2020. <http://www.chinanews.com/gn/2020/02-28/9108273.shtml> (accessed Feb 28, 2020).
- 52 CGTN. What's the main aggravating factor in Wuhan's coronavirus crisis? Feb 6, 2020. <https://news.cgtn.com/news/2020-02-06/What-s-the-main-aggravating-factor-in-Wuhan-s-coronavirus-crisis--NRw1AXX2zC/index.html> (accessed March 13, 2020).
- 53 IFeng News. Health workers in Fangcang shelter hospitals: unlike normal hospitals, health workers also provide patients with care that is necessary for essential living (in Chinese). Feb 21, 2020. <https://finance.ifeng.com/c/7uF3RNb7f0e> (accessed March 13, 2020).
- 54 People's Daily. Coronavirus patients stun netizens with their optimism. Feb 10, 2020. <http://en.people.cn/n3/2020/0210/c98649-9656168.html> (accessed March 13, 2020).
- 55 China Daily. Patients stay optimistic, entertained at Wuhan hospital. Feb 11, 2020. <https://www.chinadaily.com.cn/a/202002/11/WS5e4245b6a310128217276aa7.html> (accessed March 13, 2020).
- 56 Xinhua News. Makeshift hospitals start to accept patients in China's Wuhan. Feb 5, 2020. http://www.xinhuanet.com/english/2020-02/05/c_138758792_5.htm (accessed March 13, 2020).
- 57 Xinhua News. Wuhan is racing to build Fangcang shelter hospital (in Chinese). Feb 4, 2020. http://www.xinhuanet.com/2020-02/04/c_1125528863.htm (accessed Feb 5, 2020).
- 58 China News. Wuhan plans to build 19 Fangcang shelter hospitals, providing 30,000 beds in total. Feb 24, 2020. <http://www.chinanews.com/sh/2020/02-24/9102194.shtml> (accessed Feb 25, 2020).
- 59 The Diplomat. China's 'whole-of-government' pushback on the coronavirus. Feb 11, 2020. <https://thediplomat.com/2020/02/chinas-whole-of-government-pushback-on-the-coronavirus/> (accessed March 15, 2020).

- 60 Xinhua News. The Standing Committee of the Central Political Bureau of the Communist Party of China convened meeting on prevention and control strategies for novel coronavirus disease (in Chinese). Jan 25, 2020. http://www.xinhuanet.com/politics/2020-01/25/c_1125502052.htm (accessed March 15, 2020).
- 61 The State Council of the People's Republic of China. The National Health Commission joins forces with other departments and forms the Joint Prevention and Control Mechanism of the State Council to tackle novel coronavirus disease (in Chinese). Jan 22, 2020. http://www.gov.cn/xinwen/2020-01/22/content_5471437.htm (accessed March 15, 2020).
- 62 Alahdab F, Albitar B, Muhiedeen K, Attar S, Atassi B. Field hospitals in Syria. *Lancet* 2014; **383**: 303.
- 63 The Jerusalem Post. The world's largest and most advanced underground hospital is preparing to open its doors in Northern Israel. Nov 7, 2013. <https://www.jpost.com/PromoContent/The-worlds-largest-and-most-advanced-underground-hospital-is-preparing-to-open-its-doors-in-Northern-Israel-330888> (accessed Feb 9, 2020).
- 64 You J, Mao Q. An improved ward architecture for treatment of patients with Ebola virus disease in Liberia. *Am J Trop Med Hyg* 2016; **94**: 701–03.
- 65 Aimone F. The 1918 influenza epidemic in New York City: a review of the public health response. *Public Health Rep* 2010; **125** (suppl 3): 71–79.
- 66 ABC News. Ebola outbreak: soccer stadium in Liberia to be converted to virus treatment centre, FIFA says. Sept 12, 2014. <https://www.abc.net.au/news/2014-09-12/monrovia-soccer-stadium-to-house-ebola-centre-fifa/5738710> (accessed Feb 9, 2020).
- 67 Lamb LE, Cox A, Fletcher T, McCourt A. Formulating and improving care while mitigating risk in a military Ebola virus disease treatment unit. London: British Medical Journal Publishing Group, 2017. <https://doi.org/10.1136/jramc-2015-000615>.
- 68 Vox. The US needs a lot more hospital beds to prepare for a spike in coronavirus cases. March 14, 2020. <https://www.vox.com/science-and-health/2020/3/14/21179714/coronavirus-covid-19-hospital-beds-china> (accessed March 15, 2020).
- 69 Vox. Italy's coronavirus crisis could be America's. March 13, 2020. <https://www.vox.com/2020/3/10/21171217/coronavirus-covid-19-italy-hospitals> (accessed March 15, 2020).
- 70 ABC News. Italy's health system at limit in virus-struck Lombardy. March 2, 2020. <https://abcnews.go.com/Health/wireStory/italys-health-system-limit-virus-struck-lombardy-69331977> (accessed March 10, 2020).
- 71 Bloomberg. Virus spread pushes Italian hospitals toward breaking point. March 10, 2020. <https://www.bloomberg.com/news/articles/2020-03-10/virus-spread-pushes-italian-hospitals-toward-breaking-point> (accessed March 15, 2020).
- 72 Reuters. China sends medical supplies, experts to help Italy battle coronavirus. March 13, 2020. <https://www.reuters.com/article/us-health-coronavirus-italy-respirators/china-sends-medical-supplies-experts-to-help-italy-battle-coronavirus-idUSKBN21011M> (accessed March 14, 2020).
- 73 Reuters. China sends Serbia help to halt coronavirus spreading. March 21, 2020. <https://www.reuters.com/article/health-coronavirus-serbia-china/china-sends-serbia-help-to-halt-coronavirus-spreading-idUSL8N2BE0W2> (accessed March 29, 2020).
- 74 Reuters. Constructing temporary coronavirus hospitals. March 27, 2020. <https://www.reuters.com/news/picture/constructing-temporary-coronavirus-hospital-idUSRTS374K0> (accessed March 29, 2020).
- 75 Ministry of Defence Republic of Serbia. Minister Vulin at the Belgrade Fair: the Armed Forces are preparing 3,000 beds for the treatment of patients infected with the coronavirus. March 24, 2020. <http://www.mod.gov.rs/eng/15785/ministar-vulin-na-beogradskom-sajmu-vojska-sprema-3-000-postelja-za-lecenje-zarazenih-koronavirusom-15785> (accessed March 29, 2020).
- 76 Global Times. Makeshift hospitals devised from military equipment to help Iran amid COVID-19 outbreak. March 12, 2020. <https://www.globaltimes.cn/content/1182425.shtml> (accessed March 29, 2020).
- 77 China News. They are translating documents and manuals on COVID-19 and "moving" them to Iran (in Chinese). March 12, 2020. <http://www.chinanews.com/gn/2020/03-12/9122570.shtml> (accessed March 15, 2020).
- 78 NBC News. Coverage of the COVID-19 outbreak. March 15, 2020. <https://www.youtube.com/watch?v=UVSWUDrAVHk> (accessed March 16, 2020).
- 79 Graham-Harrison E. ExCel coronavirus hospital will be by far the largest in the UK. March 26, 2020. <https://www.theguardian.com/world/2020/mar/26/excel-coronavirus-hospital-will-be-by-far-the-largest-in-the-uk> (accessed March 29, 2020).
- 80 Culbertson A. Coronavirus: Spain surpasses China COVID-19 cases as deaths rise to 7,340. March 31, 2020. <https://news.sky.com/story/coronavirus-spain-covid-19-deaths-rise-by-812-to-7-340-11965650> (accessed March 31, 2020).

© 2020 Elsevier Ltd. All rights reserved.