

# ANESTHESIOLOGY

## Establishing and Managing a Temporary Coronavirus Disease 2019 Specialty Hospital in Wuhan, China

Weihong Zhu, M.D., Yang Wang, M.D., Kui Xiao, M.D., Huilin Zhang, M.D., Yi Tian, M.D., Sean P. Clifford, M.D., Junmei Xu, M.D., Jiapeng Huang, M.D., Ph.D.

*ANESTHESIOLOGY* 2020; 132:1339–45

In December 2019, a novel and ongoing outbreak of pneumonia was reported in Wuhan city, Hubei province, China,<sup>1–4</sup> which has caused significant concerns internationally. Chinese scientists completed isolation of this novel betacoronavirus from patients in Wuhan, and it has been subsequently named coronavirus disease 2019 (COVID-19). As of March 6, 2020, a total of 80,813 laboratory-confirmed COVID-19 infections were reported in China, leading to the deaths of 3,073 patients within the country. In Wuhan alone, 49,871 COVID-19 infections have been confirmed with 2,349 deaths and 28,511 patient recoveries.<sup>5</sup> Designated hospitals which can manage COVID-19 effectively are limited in terms of bed availability, staffing, and resources. Nearly 70% of COVID-19 patients display no symptoms or only mild symptoms. Because there are more than 9 million citizens in Wuhan, the designated hospitals cannot admit all patients suspected of infection as well as provide adequate clinical care to severe or critically ill COVID-19 patients. This could lead to a severe strain on healthcare resources and poor quality of patient care.

As part of the National Emergency Team, 42 physicians and nurses and 10 medical transport ambulances from The Second Xiangya Hospital of Central South University (Changsha, China) arrived at Wuhan Wuchang Hongshan Stadium to establish a COVID-19 Specialty Ark Hospital in hopes of ameliorating the dire situation in Wuhan. Operating similarly to Mobile Medical Units during World

War II, this first COVID-19 specialty hospital established and managed by the emergency medical team has now been replicated numerous times throughout Wuhan. As of today, 17 COVID-19 specialty Ark Hospitals have been established in Wuhan, China. We aim to share our experiences in one of these temporary COVID-19 Ark Hospitals and hope to provide insights and strategies to conquer this deadly disease.<sup>5–10</sup>

### Purpose and Significance of Temporary COVID-19 Specialty Hospitals

Many asymptomatic or mildly symptomatic COVID-19 patients stay at home for isolation and do not get timely medical care, leading to spread of the illness among family members.<sup>6</sup> For patients presenting to the hospital, the most common symptoms noted were fever (43.8% on admission and 88.7% during hospitalization) and cough (67.8%). Diarrhea (3.8%) was an uncommon symptom. The median incubation period was 4 days (interquartile range, 2 to 7). On admission, ground-glass opacity was the most common radiologic finding on chest computed tomography (56.4%). In patients with nonsevere disease, no radiographic or computed tomography abnormality was demonstrated in 157 of 877 patients (17.9%); however, in those with severe disease, only 5 of 173 patients (2.9%) lacked radiologic abnormality.<sup>4</sup> A majority of cases became more severe with many patients becoming critically ill, further worsening the epidemic in Wuhan. Facing a serious public health threat, the Chinese government decided to turn stadiums, conference centers, and classrooms into infectious disease specialty “Ark Hospitals” (a temporary hospital built from preexisting nonmedical buildings) to solve the severe shortage of hospital beds in Wuhan. The construction of these facilities is guided by the following principles:

### Immediate Admission of All Potential COVID-19 Patients

The overarching goal is to control the COVID-19 epidemic macroscopically. These temporary specialty hospitals can dramatically and immediately expand the admission capacities of the whole city, reduce the burdens/patient loads of designated comprehensive hospitals, manage COVID-19 patients centrally, eliminate virus transmission routes, and protect susceptible populations from COVID-19.

### Cost Containment

Temporary specialty hospitals are cheaper and quicker to build and operate. For example, the newly opened 1,000-bed

W.Z. and Y.W. contributed equally to this article.

Submitted for publication March 7, 2020. Accepted for publication March 9, 2020. Published online first on March 18, 2020. From the Department of Orthopedic Surgery (W.Z.), National Emergency Medical Team (Y.W.), Department of Pulmonary and Critical Care Medicine (K.X.), Department of Nursing (H.Z.), Department of Infectious Diseases (Y.T.), and Department of Anesthesiology (J.X.), The Second Xiangya Hospital, Central South University, Changsha, China; Department of Anesthesiology and Perioperative Medicine, University of Louisville, Louisville, Kentucky (S.P.C., J.H.).

Copyright © 2020, the American Society of Anesthesiologists, Inc. All Rights Reserved. *Anesthesiology* 2020; 132:1339–45. DOI: 10.1097/ALN.0000000000003299

Huoshenshan comprehensive COVID-19 Hospital to provide state of the art, comprehensive and advanced care for patients, cost 1 billion RenMinBi (RMB, about \$143 million U.S. dollars). Currently, there are 12,000 beds available in temporary specialty Ark Hospitals and they only cost a total of 1.1 billion RMB (\$158 million U.S. dollars), a greater than 10-fold decrease in cost per bed.

### Fear Allayment

Ark Hospitals admit all asymptomatic COVID-19 patients and those with mild symptoms. These facilities serve to quickly contain all potential sources of infection from the public, and because all patients have the same confirmed COVID-19 virus, patient-to-patient cross infection is not present. The Ark Hospitals help to relieve the anxiety and fear among the public and encourage people to actively report and seek treatment in fighting this terrible epidemic.

### Barriers to Build and Operate a Temporary COVID-19 Specialty Hospital

There are numerous challenges in the process of building and operating a temporary specialty hospital. Major obstacles encountered by our team include the following:

#### Conversion of Civilian Building and Infrastructure into an Infectious Disease Hospital

This requires the collaboration and communication between local governments, architects, and infectious disease experts to determine the best location for patient beds, fire escape pathways, water and electricity sourcing, and common living areas while maintaining appropriate infection control within the Ark Hospital (fig. 1).<sup>7-9</sup> The goal is to admit as

many mild COVID-19 patients as possible while remaining compliant with national infection control standards.

### Staffing Challenges

The Ark Hospital is not only tasked with clinical care to admitted patients, but also the maintenance of patients' daily living activities and mental well-being. Physicians, nurses, security officers, environmental services, and many other ancillary staff are necessary to provide these services. Determining how to best use these scarce resources while training ancillary staff on strict infection control procedures is urgent and extremely challenging.

### Efficient, Coordinated Efforts

Working expeditiously in a harmonized fashion with members from many different hospitals is crucial to the success of these temporary structures. Protocols and procedures must be quickly established and staff must be centrally regulated to provide a safe, high-quality, and efficient operation in these Ark Hospitals.<sup>11,12</sup>

### Training and Supply Management

Infection control education for healthcare providers and ancillary staff are mandatory to protect themselves and patients, yet is difficult to implement because of the time constraint. In addition, ensuring adequate personal protective equipment and other medical supplies is challenging because of the tremendous need across the nation currently.<sup>13-15</sup>

### Strategies to Build and Operate a Temporary COVID-19 Specialty Hospital

In creating these temporary hospital structures, we were guided by several design strategies, including the following.



**Fig. 1.** A multidisciplinary meeting to discuss the operation of Wuchang temporary COVID-19 specialty Ark Hospital.

### Active Participation in the Infrastructure Renovation and Strict Infection Control Standards

As soon as our team arrived in Wuhan on February 4, 2020, we immediately visited the stadium and made sure the renovation could meet international infection control and treatment standards. Through close communication with our architects and engineers, we provided constructive advice on patient care area distribution, hallway design, electricity arrangement, and information network connections. This strategic planning and teamwork led to incredible production efficiency in an arduous situation. The Wuchang Ark Hospital took only 33 h from initial planning to fully operational status with full patient admittance and achievement of national hospital standards (fig. 2).<sup>6</sup>

### Smooth Coordination and Staffing Management

Wuchang Ark Hospital is located in the Hongshan Stadium and consists of a Clinical Care Ark in the stadium and Supply/Screening/Testing Arks within an assortment of ambulances (fig. 3). The intensive care unit is established inside the Clinical Care Ark. The healthcare team is a combination of the national emergency team and Wuhan local medical personnel. Within the Ark, the People's Hospital of Wuhan University serves as the leading clinical team with seven collaborating national units including the Second Xiangya Hospital of Central South University and five medical teams from the neighboring Hunan province. Currently 125 physicians, 506 nurses, and 90 administrative members work in our Wuchang Ark Hospital. The leadership team is composed of members from People's Hospital of Wuhan University, the Second Xiangya Hospital of Central South University, Shanghai Huashan Hospital (Shanghai, China), and Wuchang district government officials. We have

established multiple personnel divisions including Clinical Care, Nursing, Administrative Office, Infection Control, and Supply Chain to ensure smooth operations in the hospital.

### Standardization of Procedures and Policies

We aimed to create a broad network of personnel from many different hospitals that functionally operate as a unified team and adhere to the highest standards of care. To accomplish this goal, we developed standard procedures and policies including a patient identification verification policy, consultation policy, admission and discharge procedures, patient resuscitation flowchart, and medical waste disposal procedures to guide workflow and standards on medical, nursing, infection control, and supply chain aspects.<sup>16</sup>

The model focuses on improving medical care quality. Patients admitted to the Ark Hospital are mild cases upon presentation, and we have divided the hospital into three areas (A, B, C) so that three medical teams can be assigned. Areas A and C have 250 beds, and area B has 300 beds.

Patient therapy combines Western and traditional Chinese medicines with established expert consultation procedures. We especially focus on the elderly and patients with comorbidities secondary to the high mortality rate in this population. Fear, anxiety, and depression are common, and we provide mental health care and intervene on emotionally unstable patients. We take advantage of expertise from all members and use the full capacity of the team to discuss care plans and communicate on issues/outcomes.

Staffing wise, the ratio is 10 physicians and 40 nurses for every 100 patients in the Ark Hospital to ensure timely care of our patients (fig. 4). Our goal is to have zero infection for healthcare providers, zero in-hospital deaths among admitted patients, and zero readmission for discharged patients. It is important to clarify that our Ark Hospital only admits



**Fig. 2.** Bird's eye view of Wuchang temporary COVID-19 specialty Ark Hospital.





**Fig. 3.** Screening Ark in vehicles for Wuchang Ark Hospital.



**Fig. 4.** A physician (J.X.) communicates with a COVID-19 patient inside Wuchang Ark Hospital.

patients with mild COVID-19 symptoms; patients with severe diseases are transferred to comprehensive hospitals.

### Emergent Education and Implementation of Infection Control Measures

As noted, Wuchang Ark hospital is divided into areas A, B, and C and can admit about 800 patients at its maximal capacity. The Second Xiangya Hospital of Central South University team is responsible for the 250 beds in area A. Upon Ark implementation, our infectious disease experts immediately provided infection control/prevention training, live demonstration of how to use personal protective

equipment, and showcased level 2 and level 3 infection control procedures. Level 1 infection control entails scrub, disposable hat, disposable gown, and disposable surgical mask, which should be changed every 4 h or when it is moist or contaminated. Level 2 infection control consists of disposable hat, medical masks (N95 or above), eye/face shields (anti-fog), scrub, disposable gloves, and disposable shoe covers. Level 3 infection control procedures are composed of all level 2 requirements and replace eye/face shields with positive pressure respirator hoods. The Ark Hospital is organized into a Clean Zone, Dirty Zone, and Contaminated Zone. Our Division of Infectious Disease provided 13 sessions to

educate more than 500 physicians, nurses, policemen, security, and environmental services. For our team of more than 450 nurses, we provided training with lectures, simulations, and live demonstrations on proper throat swab procedures in COVID-19 patients for testing.<sup>13,14</sup>

### Supply Preparation and Logistics Management

Frontline leadership and the National Health Commission coordinated with local government public health departments to ensure adequate personal protective equipment for healthcare providers as well as daily necessities. Special attention is paid to fulfill the personal needs of patients if possible to help relieve their anxiety.<sup>6</sup>

### Achievements of Temporary COVID-19 Specialty Ark Hospitals

As described below, the construction of these Ark Hospitals has had a significant impact in the Wuhan community as noted in clinical outcomes, control of the epidemic, and public health impact:

#### Clinical Outcomes

Our goal is to ensure that all admitted patients receive rapid treatment and supportive therapy. We empirically start antiviral therapy with arbidol hydrochloride, oseltamivir, and ribavirin by mouth. Traditional Chinese medicines are also provided to all patients and include lianhuaqingwen capsule, qingfei paidu decoction,<sup>17</sup> feilike mixture, and magnesium isoglycyrrhizinate injection. In addition, atomized interferon plus steroid are used for breathing treatments. If patients demonstrate clinical or radiographic signs of pulmonary infection, mosifloxacin is added to the regimen. Although

there are no randomized trials to confirm the effectiveness of these agents, they are considered likely helpful in COVID-19 patients, and the cost of these medications is usually modest. The comorbidities of elderly patients are managed accordingly. Counseling is provided to all patients if desired, and multiple activities are arranged to relax patients and improve the patient–physician relationship. Our team initiated radiologic and laboratory work with completion of 320 X-rays, 239 computed tomography-scans, 671 complete blood counts and C-reactive protein assays, and 340 IgM/IgG antibody titers of COVID-19 patients to guide the assessment of the disease and discharge criteria (fig. 5). Currently, our team is responsible for 249 beds, we have admitted 411 patients and discharged 217 patients, and we demonstrate a cure rate of 52.3%. This cure rate is currently the highest among the 17 Ark Hospitals in Wuhan, China.

#### Control of COVID-19 Epidemic

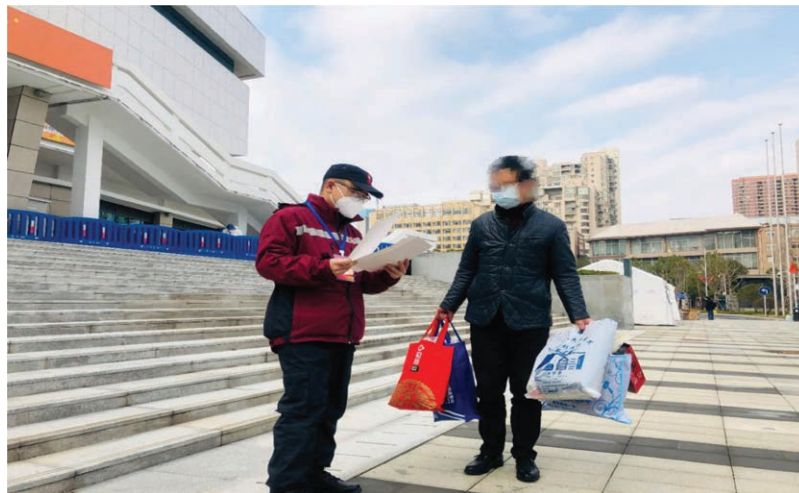
The entire 785-bed Wuchang Ark Hospital has admitted more than 1,100 patients, discharged 500 patients (fig. 6), greatly relieved the burdens of designated comprehensive hospitals, effectively controlled the infectious source, halted the virus transmission route, and certainly assisted in protecting the public.<sup>18,19</sup> We have established a successful mechanism for quality control and achieved a zero infection rate for healthcare providers, a zero in-hospital death rate for patients presenting with mild COVID-19 symptoms, and a zero readmission rate. Our experience in this endeavor is being used by Ark hospitals throughout China.

#### Public Health Impact

A temporary COVID-19 specialty hospital model significantly improved the diagnosis, admission, isolation, and treatment



**Fig. 5.** Laboratory testing for novel coronavirus by physicians and technicians in the Screening/Testing Ark.



**Fig. 6.** A COVID-19 patient is ready to be discharged from the Ark Hospital.

challenges occurring during a major epidemic. Overcoming these obstacles is critical in ensuring that every patient can receive standard and effective treatment, which in effect enhances the confidence of the patient population and reduces the burdens on the government. The model demonstrated has greatly contributed to the timely control of a new and widespread epidemic. Currently, two of the 17 Ark Hospitals have been successfully retired as better control of the COVID-19 epidemic has now been achieved in Wuhan, China.

## Conclusions

The establishment and operation of temporary COVID-19 specialty hospitals proved to be useful in the control of an infectious crisis within Wuhan, China and will hopefully provide a blueprint for the management of future epidemiologic disasters.

## Research Support

Support for this study was provided solely from institutional and/or departmental sources.

## Competing Interests

The authors declare no competing interests.

## Correspondence

Address correspondence to Dr. Xu: Department of Anesthesiology, The Second Xiangya Hospital, Central South University, 139 Middle Renmin Road, Changsha, Hunan Province 410011, China. 13975148864@139.com. Information on purchasing reprints may be found at [www.anesthesiology.org](http://www.anesthesiology.org) or on the masthead page at the

beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

## References

1. Wang C, Horby PW, Hayden FG, Gao GF: A novel coronavirus outbreak of global health concern. *Lancet* 2020; 395:P470–3
2. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X: Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020; 395:P497–506
3. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, Zhao X, Huang B, Shi W, Lu R, Niu P, Zhan F, Ma X, Wang D, Xu W, Wu G, Gao GF, Tan W: A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med* 2020; 382:727–33
4. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, Liu L, Shan H, Lei CL, Hui DSC, Du B, Li LJ, Zeng G, Yuen KY, Chen RC, Tang CL, Wang T, Chen PY, Xiang J, Li SY, Wang JL, Liang ZJ, Peng YX, Wei L, Liu Y, Hu YH, Peng P, Wang JM, Liu JY, Chen Z, Li G, Zheng ZJ, Qiu SQ, Luo J, Ye CJ, Zhu SY, Zhong NS; China Medical Treatment Expert Group for Covid-19: Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med* 2020 [Epub ahead of print]. DOI: 10.1056/NEJMoa2002032
5. Ministry of Health of China: Epidemic Bulletin: Update on the new coronavirus pneumonia outbreak as of 24:00 on 6 March. Available at: <http://www.nhc.gov.cn/xcs/yqtb/202003/4cda391851a544279cb36f334944ca6e.shtml>. Accessed March 6, 2020.



6. Zhang B, Xiao H, Li C, Li Z: Rapid information support system for Ark Hospitals during the novel coronavirus prevention and treatment. *Chin Hosp Manage* 2020 [Epub ahead of print]. Available at: <http://kns.cnki.net/kcms/detail/23.1041.C.20200227.2206.024.html>. Accessed March 6, 2020.
7. Lin X, Zhang H, Zhang L, Li D, Wang K: Exploration of management strategies for military ark hospital medical equipment. *Chin Med Equip J* 2018;39:86–88
8. Jian G, Zheng R, Ye C: Study of standard procedures in rapid implementation of mobile Ark Hospitals. *Chin J Disaster Med* 2019; 7:551–4
9. Qin X, Hu Y, Wei Z, You X, Yu M, Wu J, Li X, Wang T, Wu P, Xu Z: Design of water supply, sewage and fire safety system in Arks Hospitals–Jiangxia Dahuashan outdoor table tennis and badminton stadium renovation. *Water Wastewater Eng* 2020 [Epub ahead of print]. Available at: <http://kns.cnki.net/kcms/detail/11.4972.TU.20200221.1457.002.html>. Accessed March 6, 2020.
10. Xinhuanet: Wuhan opens 13 “Ark Hospitals.” *Jiangxi Building Materials* 2020 [Epub ahead of print]. Available at: [http://www.cnr.cn/hubei/yaowen/20200205/t20200205\\_524961016.shtml](http://www.cnr.cn/hubei/yaowen/20200205/t20200205_524961016.shtml). Accessed March 6, 2020.
11. Shi J, Feng G, Huang W: Implications of modern hospital management policies and implantation pathways. *Chin Hosp Manage* 2020; 40:1–4
12. Huang X, Wei J, Zou D: Tertiary hospital policy implementation and study. *Chin Hosp Manage* 2020; 40:89–91
13. Wu A, Huang X, Li C, Li L: Novel coronavirus (2019-nCoV) pneumonia in medical institutions: problems in prevention and control. *Chin J Infect Control* 2020; 19:1–6
14. Li L, Wu A: Confusion on prevention and control of healthcare-associated infection of novel coronavirus. *Chin J Infect Control* 2020; 19:105–8
15. Xu H, Hu S, Fu J, Shu Q, Chen Z, Sun W, Wang D, Zhu H, Zhou H, Huang G, Fu Z, Zhao H, Wang B, Wu X, Liang Y, Huang Y, Gu M, Wang W: Recommendations for prevention and control of 2019 novel coronavirus infection among children. *Chin J Hosp Admin* 2020; 36:E001–E001. DOI: 10.3760/cma.j.issn.1000-6672.2020.0001
16. Ren Y, Zhang X, Li J, Wang Y, San J, Nai C: Tongji Medical College Huazhong University of Science & Technology experiences on novel coronavirus epidemic prevention and treatment information system support. *Chin J Hosp Admin* 2020; 36:E003–E003. DOI: 10.3760/cma.j.issn.1000-6672.2020.0003
17. State Administration of Traditional Chinese Medicine: Recommendation the use of “Qingfei detoxification soup” for the treatment of the novel coronavirus pneumonia, February 7, 2020. Available at: <http://yzs.satcm.gov.cn/zhengcewenjian/2020-02-07/12876.html>. Accessed March 6, 2020.
18. Xie X, Zhong Z, Zhao W: Chest CT for typical 2019-nCoV pneumonia: Relationship to negative RT-PCR testing. *Radiology* 2020, 200343 [Epub ahead of print]. DOI: 10.1148/radiol.2020200343
19. Li Q, Guan X, Wu P: Early Transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med* 2020, 29 [Epub ahead of print]. DOI: 10.1056/NEJMoa2001316