



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.



ELSEVIER

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Lesson learned from China regarding use of personal protective equipment

Mingkun Zhan MMed^a, Robert L. Anders DrPH, ANEF, FAAN^{b,*}, Bihua Lin BSN^a, Min Zhang PharmD, BCPS^c, Xiaosong Chen MD, PhD^a^a Department of Plastic Surgery, Fujian Medical University Union Hospital, Fujian Medical University, Fuzhou, China^b School of Nursing, University of Texas at El Paso, El Paso, TX, USA^c Department of Pharmacy, Boston Medical Center, Boston, MA, USA

Key Words:

COVID-19
Nurse
Health care worker infection
Nurses death from COVID-19

Background: In Wuhan, China, in December 2019, the novel coronavirus was detected. The virus causing COVID-19 was related to a coronavirus named severe acute respiratory syndrome coronavirus (SARS-CoV). The virus caused an epidemic in China and was quickly contained in 2003. Although coming from the same family of viruses and sharing certain transmissibility factors, the local health institutions in China had no experience with this new virus, subsequently named SARS-CoV-2.

Methods: Based on their prior experience with the 2003 SARS epidemic, health authorities in China recognized the need for personal protective equipment (PPE). Existing PPE and protocols were limited and reflected early experience with SARS; however, as additional PPE supplies became available, designated COVID-19 hospitals in Hubei Province adopted the World Health Organization guidelines for Ebola to create a protocol specific for treating patients with COVID-19.

Results: This article describes the PPE and protocol for its safe and effective deployment and the implementation of designated hospital units for COVID-19 patients. To date, only 2 nurses working in China who contracted SARS-CoV-2 have died from COVID-19 in the early period of the epidemic (February 11 and 14, 2020).

Conclusions: The lessons learned by health care workers in China are shared in the hope of preventing future occupational exposure.

© 2020 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.

In December 2019, a hospital in Wuhan, Hubei Province, reported several cases of severe unexplained viral pneumonia. The outbreak appeared just before the Spring Festival, one of China's most significant holidays. Millions of people traveled during the holiday. The government scrambled to determine the etiology of the disease. The first patients began seeking medical care with symptoms of respiratory distress, headaches, and fever. Initially, the diagnosis was an upper respiratory infection and treated with standard therapy for influenza-like illness. As the number of infected patients continued to increase rapidly, and the treatments administered did not seem to improve patients' conditions, further investigations were necessary.

There were approximately 117,100 health care workers (HCWs) in Wuhan, which could be called upon to provide care for this emerging epidemic. Quickly, the health care facilities became overwhelmed with patients. As a result of working long hours under very stressful conditions, there were reported deaths of HCWs. Throughout the epidemic, 42,600 travel nurses and physicians came into Hubei Province, primarily to Wuhan from throughout China to provide relief to the Wuhan HCWs.¹

AIMS

The paper focuses primarily on the use of personal protective equipment (PPE) to help prevent transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to HCWs. The aim is to provide more detail regarding level-3 protection protocols used at designated COVID-19 hospitals in Hubei Province to prevent the spread of the virus to HCWs.

* Address correspondence to Robert L. Anders DrPH, ANEF, FAAN, 500 W University Ave, University of Texas at El Paso, El Paso, TX 79968.

E-mail address: rlanders@utep.edu (R.L. Anders).

Conflicts of interest: There is no conflict of interest.

Author contributions: All authors contributed equally to this manuscript.

METHODS

Challenges related to insufficient PPE

Traditional methods to prevent exposure of HCWs to infected droplets or aerosolized virus particles require PPE. However, PPE availability was somewhat limited initially due to the temporary closure of the major manufacturers of PPE in China during the Spring Festival and the lockdown measures instituted to control the spread of the virus. Because SARS-CoV-2 appeared to be highly contagious, a strict PPE protocol would be required. Due to overwhelming numbers of severely ill patients and the exhausting workload of the HCWs, it became clear that significant changes to staffing and patient management would be necessary. As much as possible, all patients infected with the virus requiring hospitalization in Hubei Province were admitted to designated COVID-19 hospitals. Two hospitals designated to accept COVID-19 patients specialized in infectious diseases; an additional 51 general hospitals, 2 new temporary hospitals, and 16 Fangcang shelter hospitals were also prepared as designated COVID-19 hospitals in Wuhan.

As existing supplies of PPE were depleted, requests were made to manufacturers within China as well as international organizations to secure additional equipment and supplies. On January 21, 2020, the National Health Commission of the People's Republic of China took the lead in establishing the Joint Prevention and Control Mechanism of the State Council for COVID-19. The Ministry of Industry and Information Technology coordinated the supply of PPE in the whole country. Thus, the supply of PPE gradually met the needs of designated COVID-19 hospitals.²

Protocol emergence for the use of PPE

The methods to protect HCWs, designated as level-3 protection in China, included a personal protection protocol for proper use of PPE with coveralls and procedures for changes to the flow of patients and personnel through the designated COVID-19 hospitals.³ During the Ebola outbreak, the World Health Organization (WHO) had recommended extensive guidance on the protection of HCWs.⁴ Biosafety level-3 protection is well known in laboratories that handle dangerous and potentially lethal microbes transmitted by droplets or aerosols. There are many similarities between the recommendations for the protection of laboratory workers and the WHO recommendations for PPE to protect bedside care providers from filovirus disease. After comparing the existing recommendations, all designated COVID-19 hospitals adopted the recommendations endorsed by the WHO for filovirus disease (Ebola). The recommendation ensures protection from head to toe using the coveralls (not the gown), thus minimizing any areas of skin exposure, in combination with the lockdown of designated COVID hospitals.⁴

Revised PPE protocols and lockdown at COVID-19 hospitals

Hospital units treating COVID-19 patients were locked, meaning only personnel wearing the proper protective equipment were allowed entry, and non-COVID-19 patients were not admitted. Most of these units did not have a negative pressure system. Air disinfectant machines that operated 24 hours per day were used in the isolation units and in the transition unit (where removal of the PPE occurred).

Upon arrival at the hospital, nursing and physician staff entered the clean areas through a staff-dedicated hallway; patients arrived through another patient-dedicated entrance. Additionally, there were separate elevators for staff and patients. The temperature of HCWs was measured on entrance. HCWs with a temperature of more than 37.2°C (99°F) were not allowed to enter the hallway.

In the clean areas, staff would begin following a standardized procedure for donning PPE. The WHO Ebola PPE protocol includes a first layer of a scrub suit, followed by rubber boots (which were too cumbersome for work in the isolation unit) or closed-toe shoes with shoe covers, 2 layers of gloves, coverall, face mask, face shield/goggles, a head and neck covering, a surgical bonnet covering the neck and sides of the head or a hood, and a disposable waterproof apron.⁵ The adopted COVID-19 protocol included a hospital-provided scrub suit, complete covering of the foot and ankles with socks covered by plastic wrap and closed shoes with 2 layers of boot covers (substituted for the heavy rubber boots), 3 layers of gloves, a coverall, N95 face mask, surgical mask, face shield/goggles, hood with 2 layers of head covering, and a disposable waterproof surgical gown. The rubber boots were available for staff to wear from the transition unit to home or hotel.

Before starting the 4-hour shift (primarily for nurses) and a 6-hour shift (physicians), the staff arrived in the clean areas where a 1-way hall led to the locked isolation unit. Most of medical and nursing staff wore diapers instead of leaving the unit to use the bathroom. There are various approaches to donning and removing the PPE; posters developed by the WHO were available to staff for reference.⁵ Using 0.5% w/v isopropyl alcohol, 75% v/v is the first step in performing hand hygiene. A total of 17 steps were involved in donning the PPE as described in the adopted protocol above.

At the end of a 4- or 6-hour shift, staff moved to a transition unit, located outside of the locked isolation unit where the PPE removal and decontamination process began. The removal of PPE is a time with a high risk of contamination. The process started with washing the gloved hands with a solution of isopropyl alcohol; hand sanitizing is also recommended after the removal of each piece of PPE. When taking off the surgical gown and coveralls, ensure the front is folded inward to minimize the possibility of contamination. It is recommended the gloves be removed during this step and turned inward as well. All contaminated PPE must be disposed of properly. After removal of the N95 mask, it is recommended a surgical facemask be worn.

After removal of the PPE, the staff then proceeds to the clean unit. The steps in [Table 1](#) are our recommendations for additional decontamination. The WHO protocol is silent on the steps to be taken after the PPE is removed. Each agency needs to adapt the process to meet their goals for staff safety. [Table 1](#) illustrates only 1 method, which was the method used in COVID-19 facilities in Hubei Province.

In Wuhan, the entire process of transitioning from the hotel (for travel nurses and physicians), donning PPE, working their shift, removing the PPE, and returning home could take up to 10 hours. Thus, the staff had extensive time spent in preparing, providing care, or decontaminating before going home. Isolation was encouraged to continue at the hotel or home to protect others from potential infection.

OUTCOMES

As early as January 23, 2020, a total of 176 members of the HCWs were clinically or laboratory diagnosed with COVID-19.⁶ Since that time, with the implementation of the level-3 protection protocols and the implementation of COVID-designated hospitals, the number of HCWs diagnosed with COVID-19 has decreased.⁶ According to the Chinese Red Cross Foundation (CRCF), as of June 2, 2020, a total of 3,623 HCWs have been diagnosed with laboratory-confirmed or clinically confirmed COVID-19 throughout mainland China. A total of 31 HCWs had died from COVID-19.⁶ Only 2 nurses were infected with SARS-CoV-2 while performing their duties and then died from COVID-19.^{7,8} No other deaths from COVID-19 of nurses who had worked in mainland China during the epidemic have been reported.

In the United States as of April 9, 2020, there were 9,282 HCW with COVID-19 and of these 73% were women.⁹ Investigators noted

Table 1
Steps after PPE has been removed

- 1 Use a disposable mask.
- 2 Clean the nasal cavity and ear canal with an alcohol swab.
- 3 Rinse with normal saline.
- 4 Shower and change to clean clothes and rubber boots.
- 5 Arrive at hotel/home, clean boots with disinfectant and remove them (leave them at the designated area in the lobby of the hotel), and change to slippers.
- 6 Remove and leave the jacket provided by the hospital at the designated area of the hotel lobby and change to the coat (the coat was sprayed with chlorine disinfectant every 4 hours).
- 7 Leave slippers outside of the individual room or home and change to house slippers.
- 8 Perform hand hygiene with a solution of isopropyl alcohol, then remove the coat and leave in the area near the door to the room or home.
- 9 Take a full-body bath with soap and move to a clean area of the room to change to a different pair of slippers.
- 10 Clean the nasal cavity and ear canal with an alcohol swab.
- 11 Use mouth wash before eating.
- 12 Use eye drops (norfloxacin) to avoid mucosal infection.

Source: Summary of recommendations from designated COVID-19 hospitals in Hubei province.

that the number of cases among HCWs in the study was likely an underestimation, as health care status was missing for 84% of patients reported nationwide. As of April 8, 2020, WHO had been recording 22,073 cases of COVID-19 among HCWs from 52 countries. Nevertheless, there is currently no formal documentation of HCWs with COVID-19 to the WHO. The true number of HCWs with COVID-19 worldwide is potentially underrepresented.¹⁰

Liu et al in a cross-sectional study of 4 hospitals in Wuhan, China found that of 420 travel HCWs caring for COVID-19, none were infected with SARS-CoV-2.¹¹ The authors concluded the use of effective PPE is contributed to there being no infections among those HCWs. Their findings are consistent with the support recommendations in this study.

DISCUSSION

The experience in designated COVID-19 hospitals demonstrates the evolution of how HCWs reacted to COVID-19 in Wuhan and Hubei Province. The lack of adequate PPE was a contributor to the number of HCWs initially infected with SARS-CoV-2. Many asymptomatic patients were seen for non-COVID-related conditions unknowingly exposed to some HCWs in the outpatient clinics, which also contributed to the infection rate.

The PPE protocols implemented in designated COVID-19 hospitals are thought to have prevented a higher transmission of SARS-CoV-2 and the deaths of HCWs. Having dedicated hospitals for managing COVID-19 patients is also likely another major contributor to decreasing the infection rate among HCWs. The combination of level-3 protection of HCWs and the lockdown of designated COVID-19 hospitals worked together to provide a very high and sustainable level of protection for the doctors and nurses, who otherwise would have been at considerable risk for contracting SARS-CoV-2.

Approximately 90% of the 28,600 travel nurses were under age 40, and 25,300 travel nurses were women.¹² The nurses, for the most part, did not have underlying medical issues that might place them at risk.¹⁰ Younger age and gender has proven in some way to be protective.^{13,14} A Cochrane Systematic Review of PPE supports the importance of putting on the PPE correctly, that it may be uncomfortable to wear, and there is a risk of contamination with removing it.^{15,16}

Before implementing the PPE protocols, nurses may have placed a greater emphasis on washing their hands, using gloves, and wearing a face mask and hair covering more frequently than other HCWs (M. Zhan, and B. Lin, personal communication May 2, 2020). However, the rapid adoption of a level-3 protection and careful use of PPE including coveralls was most likely a significant factor in protecting the nurses and other HCWs from infection (Table 2).

Table 2
Summary of lessons learned

- Dedicated hallway for health care workers (HCWs) and another for patients
- Defined process of donning and removing PPE
- Double layer outer garment diminishes the risk of contamination
- Designated COVID-19 hospitals assisted in decreasing the spread of SARS-CoV-2
- Three specific units
 - The clean area provides a safe environment to don PPE including coveralls
 - The isolation unit for COVID-19 patients
 - The transition unit allows to safe disposal of PPE
- HCWs remain in the unit until the shift is over
- Personal isolation of HCWs at home protects others from the potential transmission

The previous experience with SARS did pave the way for a quicker mobilization of resources and nursing and medical staff to support the Wuhan HCWs. However, given the nature of SARS-CoV-2 and its highly infectious properties, until adequate PPE could be acquired, HCWs were infected. It does appear from the data from CRCF that relatively few HCWs were infected and died.

As of May 8, 2020, 3,514 HCWs with COVID-19 were clinically or laboratory diagnosed in mainland China on the data from the CRCF.⁷ The number of HCWs with COVID-19 rapidly reduced with the advent of the PPE. In Wuhan, out of 117,100 HCWs, 2,897 were diagnosed with COVID-19. The overall infection rate is 2.47%. The infection rate in HCWs was significantly higher than the general population in Wuhan. However, as of March 31, none of the 42,600 travel HCWs who went to Hubei Province to care for patients with COVID-19 in designated COVID-19 hospitals were known to have been infected with SARS-CoV-2.^{17,18} As of May 8, 2020, 22 HCWs in Wuhan died from COVID-19 among the 2,897 HCWs with COVID-19, and the fatality rate was 0.76%.⁶ Most of the early infections occurred before the adoption of level-3 protection.

RELEVANCE TO CLINICAL PRACTICE

The report provides useful insight for developing future strategies to deal with infectious disease pandemics. The need for continued preparedness is paramount. Policymakers must assume that there will be another epidemic. It may be the SARS-COV-2 re-emerging in the fall of 2020 or perhaps another viral agent. Public health officials working in collaboration with federal, state, and local health departments must plan for the next epidemic.

There needs to be a federal (national) and provisional (state) stockpile of PPE including coveralls and other necessary supplies required to care for patients with infectious diseases. There needs to

be a method of ensuring that supplies are kept secure, and as they become outdated are rotated with new ones. The need for planning and funding for such including the necessary equipment and supplies is critical. Failure to plan may mean additional lives lost. Other hospital units beyond the ones used in this pandemic also need to be identified. Providing temporary hospital beds or arranging for infection control units within existing facilities should be a high priority for planners. There could potentially be a more significant number of infected individuals in the second go-around of an infectious disease if safeguards should diminish.

Critical is the creation of protocols such as the one used in China. There appears to be a need for the development and implementation of educational modules for health care providers regarding the management of infectious diseases. Not only the medical components of treatment but also how to properly don and remove the necessary PPE should be included in educational protocol. Breaches in infection can occur if the PPE is not used correctly. Other considerations are limiting the time exposure that staff has to the COVID-19 patients. In China, the typical shift was 4 hours, followed by adequate time to don and take off the PPE and follow the other decontamination procedures.

Based on the China experience, there is a need to ensure appropriately configured hospital areas to managed COVID-19 patients as well as provide clean rooms and transition workspaces. The level-3 protection protocols demonstrate having appropriate spaces for staff and patients aids in preventing the spread of SARS-CoV-2.

Last, there needs to be continuing health monitoring of HCWs. Temperature checks of staff prior and after finishing their shifts could be a way of helping to determine the development of any emerging infectious disease. The use of smartphone devices in which HCWs and their significant others are requested to report daily their health status may also be useful. The use of smartphone devices has shown useful to track COVID-19.¹⁹

CONCLUSIONS

The current rate of infection has dramatically declined. The environmental controls limiting social contact and mobility have helped to create a safer environment. Readily available testing for suspected individuals with COVID-19 has helped to identify those who may be at risk quickly. As a result of the level-3 protection protocols combined with admitting patients to only COVID-19 designated hospitals, the number of HCWs infected declined significantly since mid-February 2020. Our experience may help other health systems better cope with outbreaks of the highly contagious SARS-CoV-2.

Acknowledgments

We want to acknowledge all state, local, and territorial health departments and personnel in China, working in and supporting the designated COVID-19 hospitals in China. A special thanks to Charon A. Pierson, PhD, GNP, FAAN, FAANP, Editor Emeritus, Journal of the

American Association of Nurse Practitioners for her medical editing support.

References

1. National Health Commission of the People's Republic of China. Transcript of the press conference of the Information Office of the State Council on March 31, 2020 (in Chinese). 2020. Available at: <http://www.nhc.gov.cn/xcs/yqfkd/202003/26403157baf8418292f3f69110af1d1e.shtml>. Accessed March 31, 2020.
2. Ministry of Industry and Information Technology of the People's Republic of China. Response to social concerns on hot topics such as alleviating the current shortage of medical supplies in China (in Chinese). 2020. Available at: <http://www.miit.gov.cn/n1146290/n1146402/n7039597/c7661544/content.html>. Accessed February 2, 2020.
3. National Health Commission of the People's Republic of China. Technical guidelines on prevention and control of novel coronavirus infection in medical institutions (first edition) (in Chinese). 2020. Available at: <http://www.nhc.gov.cn/yzygj/s7659/202001/b91fdab7c304431eb082d67847d27e14.shtml>. Accessed January 23, 2020.
4. World Health Organization. Personal protective equipment for use in a filovirus disease outbreak—rapid advice guideline. 2016. Available at: <https://apps.who.int/iris/bitstream/handle/10665/251426/9789241549721-eng.pdf;jsessionid=ADB728CCFA0E328A4854EC3D915D7C80?sequence=1>. Accessed January 20, 2020.
5. World Health Organization. How to put on and how to remove personal protective equipment – posters. 2015. Available at: <https://www.who.int/csr/resources/publications/ebola/ppe-steps/en/>. Accessed January 20, 2020.
6. Chinese Red Cross Foundation. Public announcement (in Chinese). 2020. Available at: <https://new.crcf.org.cn/article/20534>. Accessed June 15, 2020.
7. Chinese Red Cross Foundation. Public announcement (in Chinese). 2020. Available at: <https://www.crcf.org.cn/article/20268>. Accessed June 15, 2020.
8. Chinese Red Cross Foundation. Public announcement (in Chinese). 2020. Available at: <https://www.crcf.org.cn/article/19689>. Accessed June 15, 2020.
9. CDC COVID-19 Response Team. Characteristics of health care personnel with COVID-19—United States, February 12–April 9, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;69:477–481.
10. World Health Organization. *Coronavirus Disease 2019 (COVID-19) Situation Report –82*. World Health Organization; 2020. Available at: <https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200411-sitrep-82-covid-19.pdf>. Accessed August 25, 2020.
11. Liu M, Cheng SZ, Xu KW, et al. Use of personal protective equipment against coronavirus disease 2019 by healthcare professionals in Wuhan, China: cross sectional study. *BMJ.* 2020;369:m2195.
12. National Health Commission of the People's Republic of China. Transcript of the press conference of the Information Office of the State Council (in Chinese). 2020. Available at: <http://www.nhc.gov.cn/xcs/fkdt/202004/35b23a66a5cd4ee2a643c2719811081e.shtml>. Accessed April 9, 2020.
13. Centers for Disease Control and Prevention. Situation summary on coronavirus disease 2019 (COVID-19). 2020. Available at: <https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/summary.html#risk-assessment>. Accessed May 13, 2020.
14. Walter LA, McGregor AJ. Sex- and gender-specific observations and implications for COVID-19. *West J Emerg Med.* 2020;21:507–509.
15. Verbeek JH, Rajamaki B, Ijaz S, et al. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in health-care staff. *Cochrane Database Syst Rev.* 2020;4: CD011621.
16. Verbeek JH, Rajamaki B, Ijaz S, et al. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in health-care staff. *Cochrane Database Syst Rev.* 2020;5: CD011621.
17. National Health Commission of the People's Republic of China. Transcript of the press conference of the information office of the state council on March 31, 2020. 2020. Available at: <http://www.nhc.gov.cn/xcs/yqfkd/202003/26403157baf8418292f3f69110af1d1e.shtml>. Accessed May 2, 2020.
18. Zhan M, Qin Y, Xue X, Zhu S. Death from COVID-19 of 23 health care workers in China. *N Engl J Med.* 2020;382:2267–2268.
19. Bond S. Apple and google build smartphone tool to track COVID-19. *NPR New.* 2020. Available at: <https://www.npr.org/sections/coronavirus-live-updates/2020/04/10/831912284/apple-and-google-build-smartphone-tool-to-track-covid-19>. Accessed June 1, 2020.