

Outbreak and Regression of COVID-19 Epidemic Among Chinese Medical Staff

This article was published in the following Dove Press journal:
Risk Management and Healthcare Policy

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Abstract: Coronavirus disease 2019 (COVID-19) broke out first in Wuhan City, Hubei Province, China. In the process of controlling the pandemic, many Chinese medical staff (MS) were infected. We used government data, post mortem reports, and the medical literature on severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission, as well as prevention-and-control guidelines from the government, hospitals and media, to discuss the main risks factors faced by MS. We suggest that, when dealing with a similar pandemic in the future, guidance on personal protective equipment must be provided and materials reserved in advance. Also, the emergency response of medical institutions should be enhanced, and information shared with other countries facing identical severe challenges.
Keywords: COVID-19, exposure, risk, transmission, treatment

Introduction

Coronavirus disease 2019 (COVID-19) appeared in early December 2019 in Wuhan (Hubei Province, China).¹ Subsequently, the virus that causes COVID-19, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), spread from person-to-person.² The World Health Organization (WHO) declared COVID-19 to be a pandemic on 11 March 2020.

In China, >84,000 patients were confirmed to have COVID-19, 11,477 patients had severe COVID-19, and ~4600 patients died.³ Those data did not include the number of asymptomatic infections. From 1 April 2020, China started to release data on asymptomatic infections.⁴

China consumed considerable medical resources, and millions of medical staff (MS) participated in the quest to stop SARS-CoV-2 transmission. According to data released by the Chinese National Health Commission (CNHC), 3017 Chinese MS were infected with SARS-CoV-2 according to tests on SARS-CoV-2 nucleic acids, and at least 13 MS died.

It is necessary to review the data and case reports on MS and, upon combination with the medical literature, to identify the main sources of infection risks.

Materials and Methods

We used data and knowledge channels that could be traced. The first source was official data. These data included statistical data on COVID-19 from the CNHC, Chinese Center for Disease Control and Prevention (CCDCP), Health Departments of various Provinces, case reports on infected patients, and data on hospital construction and healthcare in some areas of China. Due to insufficient official data, we supplemented the infection data

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disclosed by the media, and looked for hospital data and case reports from some research reports. Second, we searched studies on the characteristics and symptoms of COVID-19, transmission channels of SARS-CoV-2, and personal protective equipment (PPE) for clinical staff published in the last 6 months. Third, the diagnosis-and-treatment plan, guidelines for prevention and control of SARS-CoV-2 infection, medical experts' public statements, and hospital-operation reports on COVID-19 were summarized.

We wished to investigate infection in MS. Hence, we adopted a multi-dimensional processing method of: literature and information; classified and extracted information about patients, hospital diagnosis and treatment systems; the working environment and working intensity of MS; PPE information and technical support of MS. We combined these data for further analyses.

Results

Data Description for Chinese MS Suffering from COVID-19

Before the CNHC and WHO issued a formal warning regarding COVID-19 on 20 January 2020, infection among MS in Wuhan City had been reported. These infections could be traced back to 14 members of a neurosurgery department infected by a COVID-19 patient during a surgical procedure. This was the first nosocomial infection case confirmed by the high-level expert group of the CNHC.⁵

Subsequently, the number of infections in MS continued to increase. The daily alarm system for COVID-19 from the CNHC was implemented on 21 January 2020. According to these bulletin data and other data released by the CCDCP, Hubei Province Health Committee, and Wuhan Municipal Health Department, 3019 MS tested positive for SARS-CoV-2 nucleic acids. Among them, 1716 MS were confirmed to have COVID-19 (Figure 1) and another 1303 MS were asymptomatic. According to official data and media reports, at least 13 MS died due to COVID-19^{6,7} (Figure 2).

Initially, we discovered five main characteristics of Chinese MS infected with SARS-CoV-2. First, infected MS were concentrated mainly in Hubei Province, of which Wuhan City reported 1080 confirmed cases, and other cities in Hubei Province reported 394 cases. Deaths were also concentrated in this area. Twelve of the 13 MS who died were in Hubei Province. Second, according to the CNHC, 422 medical institutions reported infection accidents. For example, there were 40 cases of MS infection in the Central South Hospital of Wuhan University.⁸ In Wuhan Union Hospital, >100 MS were infected,⁹ and Wuhan Central Hospital had >200 cases. These hospitals were in charge of management of severe COVID-19, there had far fewer infected medical staff in hospitals which treated mild patients. For example, among the 14 Shelter Hospitals used for treatment of patients with mild COVID-19 in Wuhan City, zero infection of MS was maintained. Third, the infected MS were distributed among various

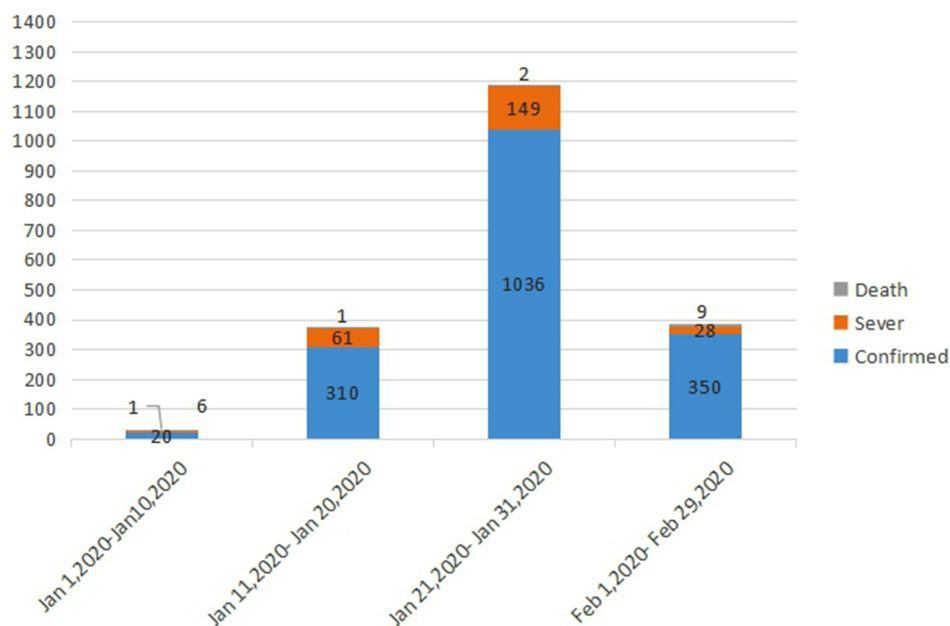


Figure 1 Statistics of Chinese medical staff affected COVID-19 (from January 2020 to February 2020, not conclude asymptomatic data).

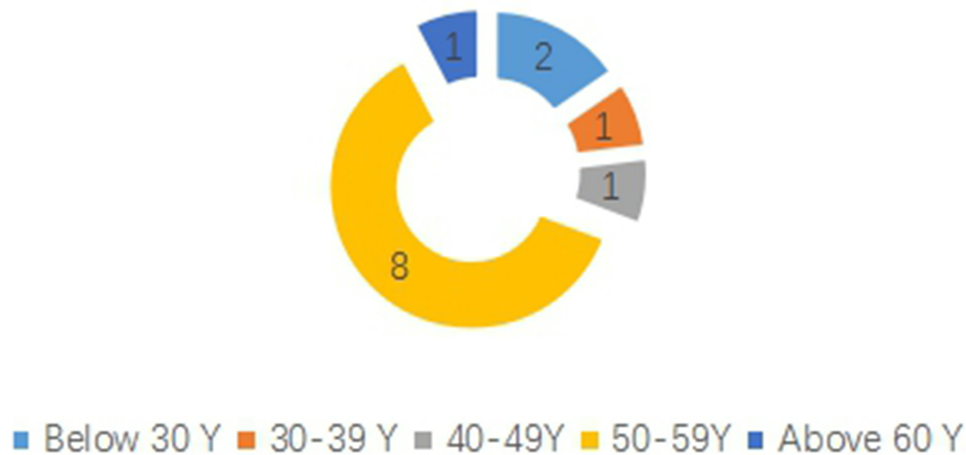


Figure 2 Age distribution of Chinese medical staff's death cases.

departments: respiratory medicine, ophthalmology, gastroenterology, neurosurgery, otolaryngology, general surgery, organ-transplantation, traditional Chinese medicine, and endocrinology. Fourth, the infection rate in the early stage of the epidemic was high, and there was no information on the later stage of infection.¹⁰ The last data released by the CNHC was on 17 February 2020, after which the number of new infections was not reported.¹¹ Fifth, the mortality rate of infected MS was low.¹² This accounted for 0.4% of MS, whereas the overall mortality rate of COVID-19 in China was ~5%.¹³

Working Environment of MS

The WHO believed that the spreading power of SARS-CoV-2 was very strong.¹⁴ The number of new infections estimated to stem from a single case (R_0) estimated by Chinese researchers was 1–2.5.¹⁵ Some researchers calculated R_0 to have reached an astonishing 5.7.¹⁶ Hospital infection and community infection were the most important infection channels.¹⁷ According to the literature, we summarized information about how hospital infection occurred.

Studies have demonstrated that SARS-CoV-2 is transmitted mainly through droplets, and that the SARS-CoV-2 concentration was high in people confirmed and suspected of being infected.¹⁸ The initial symptoms were fever, cough and other respiratory symptoms. During the diagnostic workup, MS needed to make close contact with patients. During medical treatment, patients often removed facemasks, and MS touched patients.

According to the literature, SARS-CoV-2 can also be transmitted by close contact. SARS-CoV-2 has strong vitality,¹⁹ being able to survive for 4 h on a copper surface,

24 h on cardboard, and 3 days on a plastic surface.²⁰ If the temperature and humidity are favorable, it can survive for ~7 days on a facemask surface.²¹ In the clinic and inpatient ward, the objects that patients have been exposed to and the medical instruments used by patients can become the source of infection.²² In addition, some studies have suggested that aerosols may be a transmission route.²³ In the winter, hospitals mainly use air conditioning to heat air. Hence, aerosols carrying SARS-CoV-2 can be transported readily to other places within the hospital. Some scholars have found that urine, feces, and anal swabs can contain SARS-CoV-2.²⁴ Researchers have also detected SARS-CoV-2 in the saliva, tears and conjunctival secretions of patients,²⁵ which pose a great challenge to infection control in hospitals.

Faced with this situation, hospitals in China had changed rapidly. Some regulations can be found in the files of the Health Department. This was all MS must wear masks and take temperature measurements, all hospitals had turned off the central air conditionings, even when it was still in winter, outpatient rooms and wards only used electric blankets, heating lamps and other heat preservation measures, and disinfected the air. All hospitals that had COVID-19 patients upgraded disinfection measures, completely destroyed disposable syringes, transfusion devices, contaminated gauzes and clothing, patient's domestic garbage, any other equipment and materials (clothing, bedding, towels, plates, cups, sputum boxes, toilet) that patients had ever touched were disinfected completely. Besides, chair, door handle, faucet floor, wall, door and window in hospital were disinfected regularly. Hospitals had put forward protection requirements

for medical staff. The MS working in the fever clinic and inpatient department wore surgical gowns on the inside, and then wore disposable surgical clothes. The third layer was one-piece protective clothing, the fourth layer was disposable surgical clothing. One short shoe cover inside the protective clothing, one long shoe cover outside the protective clothing, three to four layers for gloves, one N95 mask, one surgical mask, and one eyepiece to ensure the novel coronavirus was isolated in vitro.

Systems of Diagnosis and Treatment in Chinese Hospitals

In the early days of the COVID-19 pandemic, it had not been disclosed to the Chinese public that they were facing a dangerous infectious disease, but instead something akin to influenza. Patients went to hospitals as usual.²⁶ Patients would first choose a general clinic, visit the physicians in departments of internal medicine, respiratory medicine, and emergency medicine: MS in these departments had the highest frequency of making contact with patients.²⁷ In addition, some COVID-19 patients had conjunctivitis and diarrhea, so they had close contact with MS from the ophthalmology and gastroenterology departments, respectively.²⁸ Hospitalized patients were treated for viral pneumonia initially.²⁹ MS needed to carry out inspection, medication, infusion, and oxygen-supply duties for patients, and to provide mechanical ventilation and life support for patients with severe COVID-19.³⁰ They also needed to take care of the patients' daily diet, and they would have a high risk of exposure to SARS-CoV-2.³¹ In this common type of diagnosis and treatment processes, MS from several hospital departments were exposed to SARS-CoV-2, and the latter could spread widely within the hospital.

After COVID-19 had been confirmed officially, many people who had a fever or cough rushed to hospitals. In the face of a sudden increase in the number of patients, the number of MS was not sufficient. A total of 50,003 patients were noted in Wuhan City. However, data on Wuhan City from 2018 revealed 39,600 licensed physicians and 54,400 registered nurses. However, the MS of the departments of respiratory medicine, infectious disease and intensive care unit (ICU) were only a small part of the total medical staff. This disparity placed the medical system under tremendous pressure.³² Besides the departments of infectious diseases, respiratory medicine, and ICU, other MS were involved in treatment of COVID-19 patients.³³ According to data from

the Wuhan Municipal Health Commission, in the last 10 days of January 2020, 600 MS were infected.

Fortunately, this situation improved gradually. From February 2020, the CNHC began to dispatch troops and medical teams from various Provinces to support Hubei Province, and convened >45,000 MS, greatly improving the ratio of medical staff: patients in the epidemic-centered area. This MS supplementation also enabled rotation and vacation of MS. The most important feature was the change of health-policy strategies. From February 2020, the CNHC proposed a hierarchical program of diagnosis and treatment.³⁴ COVID-19 inpatients would be treated by Infectious Diseases Hospitals and specialist Respiratory Diseases Hospitals and large hospitals were designated in which other medical services were stopped. In Wuhan City, there were 37 hospitals that fitted this description. These hospitals were transformed and increased the number of PPE and medical equipment.³⁵ Other hospitals no longer treated patients with fever. Second, the Chinese Government built two hospitals in Wuhan City (Leishenshan Hospital and Huoshenshan Hospital) equipped, in total, with 2500 beds and ICU facilities, which could be employed specifically for the treatment of severe COVID-19. The MS needed by these two hospitals were from the military and medical teams of other Provinces.³⁶ Third, the Chinese Government set up 14 Shelter Hospitals in Wuhan City for the treatment of mild COVID-19.³⁷ COVID-19 patients were exposed to the new hospital and MS, and the infection rate of other peripheral MS decreased. MS nursing COVID-19 patients learned their lesson, and took strict protective measures to reduce the infection risk.³⁸

Information and Technical Support for MS

A consensus on the sources, host, incubation time, mechanism, course characteristics and transmission of SARS-CoV-2 had not been reached.³⁹ This affected the consciousness of MS with regard to PPE.

In early January 2020, the Wuhan Municipal Health Department did not identify the new virus accurately. It regarded COVID-19 as a disease similar to influenza. Nor did it require MS to take special protective measures. Although most MS wore facemasks when they were working, most of these facemasks were disposable (rather than N95 medical masks) and they did not wear gloves.⁴⁰ Until 20 January 2020, after officially confirming that COVID-19 was fatal, hospitals began to improve the level of PPE.⁴¹ The CNHC released seven versions of the COVID-19 Diagnosis and Treatment Plan.⁴² The etiologic and epidemiologic characteristics, clinical symptoms, diagnostic criteria, clinical

classification, treatment methods, as well as the criteria for hospital discharge, patient isolation and patient transfer for COVID-19 were introduced in this document. The CCDPC released two versions of The COVID-19 Prevention and Control Plan and introduced: a monitoring program for cases; a plan for epidemiologic investigation of patients; a management plan of suspicious exposures and close contacts; the technical guidelines for laboratory testing and prevention of COVID-19; case reports; specimen collection/transportation; case rescue; MS training. The WHO put forward suggestions on how to diagnose and treat patients, how to prevent air transmission of SARS-CoV-2, disinfection of medical institutions, and disposal of suspected. These actions provided more comprehensive information to physicians and nurses who had not experienced COVID-19 previously.

PPE for MS

Initially, in Hubei Province (which was the center of the epidemic), there was a severe shortage of medical devices, drugs and PPE. On the one hand, the rapid increase in the number of patients led to high consumption of medical masks, protective clothing, goggles and disinfectants. On the other hand, the original reserve of equipment was insufficient and, coupled with the traffic blockade and factory shutdowns during the Spring Festival holiday, the supply of materials was not guaranteed.³⁶ According to medical regulations, disposable masks can be replaced at any time, N95 medical masks should be replaced every 4 h, medical protective clothing cannot make contact with water, and goggles must be provided. However, from the end of January to the beginning of February 2020, not every hospital adhered to these regulations.

In order to solve these difficulties, the Chinese Government had accelerated the production and procurement of medical equipment, given priority to the supply of protective equipment for medical staff, friendly countries and Non-Governmental Organizations had also donated a large number of medical materials to hospitals. At present, China can produce 200 million disposable masks, 3.4 million N95 medical masks and 1.5 million medical protective clothing every day, which can meet the needs of medical staff.

Discussion

China, like virtually all countries, was not fully prepared for the COVID-19 epidemic. On the one hand, the scale of this pandemic was tenfold larger than that for SARS in 2003. On the other hand, China did not have the drugs and medical equipment needed for treatment of infectious

respiratory diseases. For example, China has not been able to produce extracorporeal membrane oxygenation equipment and computed-tomography (CT) equipment on a large scale. Therefore, China's main "weapon" against the COVID-19 epidemic was human resources: MS.

In recent years, the level of education and experience of MS and hospital facilities in China have improved greatly, but MS paid a heavy price when they were confronted with COVID-19. The Chinese authorities have not published their investigation into the cause of SARS-CoV-2 infection and efficiency of protection of MS. From the diagnosis-and-treatment system, working environment and working intensity, as well as the level of protection of MS within Chinese hospitals, four main risk factors can be observed. First, governments worldwide recognized that SARS-CoV-2 had many transmission channels, strong transmission, and high infectious risks.⁴³ Second, in the face of a rapidly spreading epidemic, the medical system struggled to cope.⁴⁴ Third, information on protection obtained by MS was not comprehensive, and vigilance regarding protection had not been increased to the highest level.⁴⁵ Fourth, PPE was not supplied in a timely fashion.

In addition, some hidden problems in hospital construction and dealing with emergencies in the public-health system in China were revealed. In terms of hospital construction, the scale and funding of Infectious Disease Departments in most hospitals was not sufficient to resist a large-scale epidemic.⁴⁶ In terms of dealing with emergencies in the public-health system, infection-prevention training for all MS (especially young MS) must be carried out continuously to remind them to protect themselves when dealing with new diseases.⁴⁷

Two aspects merit discussion with regard to Chinese MS infected with COVID-19. One was the scale of infection. Compared with the number of MS infected in other countries, especially in Italy and Spain, where the epidemic scale was close to that of China, there was a difference.⁴⁸ In March 2020, the National Federation of Physicians in Italy reported that 6205 medical staff had been infected with SARS-CoV-2, which accounted for 9% of confirmed cases, and 20% of them were frontline physicians, 65 of whom died. The number of Chinese MS infected with SARS-CoV-2 was relatively small, and there were two possible reasons for this phenomenon. First, the Chinese authorities counted only the physicians and nurses in public hospitals, not external staff.⁴⁹ Second, PPE in Italy was more scarce than that in China, and MS suffered more pressure.⁵⁰

Another issue worth discussion was how to reduce accidental infections. According to statistical data and case reports, the number of MS infected at the beginning of the epidemic was the largest. Of all hospital departments, the number of infections was greatest in MS of the outpatient department because most MS were not aware of the epidemic at that time and protective measures were poor. Infected MS were also distributed in the departments of internal medicine, respiratory disease, and ophthalmology because they had a high frequency of contact with the air droplets and secretions of patients. The scope of infection was more severe in large hospitals than that in small and medium-sized hospitals. This was because when people heard that COVID-19 was a high-mortality disease, they first chose a large hospital to seek reputable physicians and advanced medical facilities. However, the number of respiratory-disease departments and ICU wards in large hospitals was also limited, and could not accommodate the sudden increase in the number of patients. The crowding of patients led to a deterioration in the health environment and increased the probability of SARS-CoV-2 transmission. In short, the more patients there were, the more danger MS faced. Another group of MS who could be infected readily was physicians and nurses in the inpatient department. The patients with confirmed COVID-19 that they made contact with (especially critically ill patients) were highly infectious. SARS-CoV-2 was detected in the medical supplies and household wastes they had used. MS needed to be in contact with seriously ill COVID-19 patients 24 h a day, and the exposure risk was very high.⁵¹

Other factors should also be mentioned. First, Chinese data showed that the infection rate of MS was high at the peak of the epidemic.⁵² When the epidemic stabilized, the probability of infection declined quickly. Hence, in addition to adequate protection for MS, interruption of the infection source was very important.⁵³ In China, with construction of new hospitals specializing in treatment of severely ill COVID-19 patients and opening of “fever clinics”, the waiting time for patients to be seen decreased. The corresponding medical devices and isolation equipment were upgraded so that infectious patients were treated appropriately and the infection source reduced.⁵⁴ Second, the sufficiency of information on protection was very important. China had encountered the SARS epidemic in 2003 and other infectious respiratory diseases in recent years, and the healthcare system had gained some experience in dealing with these infections.⁵⁵ Nevertheless, the healthcare system had to focus on how to use drugs instead of preventing

infection. The key to preventing infection was to be fully informed. Early infections of some MS in the COVID-19 pandemic were due largely to MS not knowing about the highly pathogenic SARS-CoV-2 let loose in their hospital.

Conclusions

COVID-19 has become the most serious public-health disaster worldwide.⁵⁶ MS in China were the first group to fight against SARS-CoV-2. China took measures to reduce the number of newly confirmed patients to single digits within 6 months, and to ensure that the vast majority of patients were discharged from hospital successfully. These measures involved ensuring the health and “combat effectiveness” of MS. During the COVID-19 epidemic, infection of Chinese MS elicited some painful lessons: lack of PPE, inadequate information on protection, and an unscientific diagnosis-and-treatment system. These problems should prompt public-health authorities to make improvements.⁵⁷ They should help MS to establish a comprehensive protection network to prevent infection. We believe that some measures, such as increasing medical manpower, improving the level of protection, and enhancing the transparency of information, should be universal worldwide. However, it will be difficult to form a unified template for the training and deployment of MS if a public-health emergency occurs because the healthcare conditions of different countries vary.

Funding

This research was sponsored by KC Wong Magna Fund in Ningbo University.

Disclosure

The authors report no conflicts of interest in this work.

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