

The key characteristics of SARS-CoV-2 infection of humans and of the city of Wuhan that made a pandemic inevitable and unavoidable

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Abstract. The significant worldwide effects of Coronavirus disease 2019 (COVID-19) have been apparent since its outbreak. This unprecedentedly widespread virus, SARS-CoV-2, has high infectivity, asymptomatic transmission, and a long-term incubation period. These characteristics have led to the rapid spread of viruses between cities and humans. The cause of the outbreak of the epidemic in Wuhan is also due to the large population, transportation, and the healthcare system lack of public health prevention and intervention in Wuhan. This unavoidable pandemic not only because the virus has robust transmission, but also the city of Wuhan did not control the spread of the virus in the early stage of the epidemic. These factors lead to a huge public health problem worldwide.

Keyword: Public Health; Coronavirus disease 2019; COVID-19; SARS-CoV-2; Epidemiology; Primary Healthcare; Intervention.

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus that causes infectious disease coronavirus disease 2019 (COVID-19). It is a novel coronavirus that was first identified in Wuhan, China, in December 2019 [1]. As of 6 February 2023, there were 754,367,807 confirmed cases and 6,825,461 fatalities of COVID-19 worldwide reported to WHO [2]. At first, there are 27 people of hospitalized patients with unknown pneumonia had direct contact with the Huanan Seafood Wholesale Market [3]. The Huanan Seafood Wholesale Market is located in the centre of Wuhan and sells seafood, poultry and wild animals [4]. Studies have shown that the source of the virus might be the infected live mammals sold in the market [3]. This may indicate that SARS-CoV-2 is a zoonotic virus. Once people are infected with SARS-CoV-2, they can spread the virus to others, whether they have symptoms or not [1]. The virus spreads primarily through respiratory droplets when an infected person talks, coughs, or sneezes and can cause a range of symptoms from mild to severe, including fever, fatigue, loss of taste or smell, and difficulty breathing [5]. The SARS-CoV-2 virus, the cause of the COVID-19 pandemic, has several key characteristics that led to its rapid spread and high rate of infections.

2. Key Characters of SARS-CoV-2

2.1 High Infectivity

SARS-CoV-2 is a highly contagious virus. Studies have shown that the transmission routes of SARS-CoV-2 include contact, droplet, airborne, and pollutant transmission [5]. Viruses can infect other people directly or indirectly. The main route of transmission of SARS-CoV-2 is the respiratory tract [6]. The virus spreads quickly from person to person through respiratory droplets and aerosol particles. It occurs primarily through respiratory droplets generated when an infected person talks, sneezes, or coughs [1]. Aerosols might also transmit SARS-CoV-2. Aerosols are particles smaller than five μm that can remain suspended in the air for long periods of time [6]. Studies have shown that respiratory droplets can produce aerosols through evaporation [5]. In poorly ventilated rooms, the virus may even spread over long distances through aerosols [6]. Also, breathing and speaking release a large number of aerosol particles [7]. These aerosols remain infectious while suspended in the air [5]. When these particles carry the SARS-CoV-2 virus, people can easily and unknowingly inhale deep into the respiratory tract and potentially become infected. Moreover, research shows that SARS-CoV-2 can survive stably for seven days on some surfaces and may cause infection [8]. This could be a potential source of transmission for the virus.

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2.2 Asymptomatic Transmission

During the outbreak of COVID-19, many asymptomatic infections emerged. Approximately 45% of people infected with SARS-CoV-2 are asymptomatic [9]. Symptom-based screening alone cannot detect all cases of SARS-CoV-2 infection [10]. Due to the asymptomatic nature of the virus, without the test, many infected people do not know they have been infected. Although an infected person does not show symptoms of the disease, they can still spread the virus to other people [1]. Prevention of virus transmission is critical in strategies to control pandemics. However, the asymptomatic infections never show symptoms, it is difficult to detect and isolate infected individuals, and it may result in a large spread of the virus. These asymptomatic infected people may not have self-isolated or been quarantined before they knew they were infected, and even appeared in public places or areas with high traffic. Studies estimate that at least 50% of new SARS-CoV-2 infections result from exposure to infected individuals who do not have symptoms [11]. It can be seen that the transmission of asymptomatic infections is one of the reasons why the spread of the epidemic cannot be fully controlled.

2.3 Long Incubation Period

The incubation period for SARS-CoV-2 is typically 2 to 14 days. The incubation period is the time from exposure to the virus to the appearance of the first symptoms. WHO pointed out that it takes an average of 5 to 6 days for symptoms to appear from once the SARS-CoV-2 infection, and it may even take as long as 14 days [5]. Surprisingly, the virus can still spread to the public and others during the incubation period [12]. In addition, in the early stage of the incubation period, there may be insufficient virus content in the tested sample to show a positive result [13]. So having a negative test for the virus does not mean the person was not exposed to the SARS-CoV-2, which still has the potential to spread the virus. Based on the systematic review and meta-analysis from Wu et al., the average incubation period for SARS-CoV-2 is 6.57 days, the incubation period of the elderly over sixty years old is 7.43 days, and the incubation period of eighteen years old or younger is 8.82 days [14]. Even though these studies suggest that the incubation period of SARS-CoV-2 does not reach the 14 days proposed by WHO, it is still a long incubation period that might bring adverse effects to the city to control the spread of the virus. SARS-CoV-2 is characterized by high infectivity, asymptomatic transmission and long incubation period, which lead to its rapid spread and high infection rate around the world. This makes it impossible for the virus to be effectively controlled in cities and suppressed in small areas. These factors make it difficult for the city to fully cover the diagnosis and isolation of all those infected with SARS-CoV-2.

3. Key Characters of the City of Wuhan

3.1 Large Population

One of the main reasons for the rapid spread of SARS-CoV-2 in Wuhan is the city's high population density. Wuhan is the capital city of Hubei Province. And it has a population of over 11 million and is the largest city and most important transportation hub in Central China [15]. The urban population density of Wuhan is about 1,200/km² (3,200/sq mi) [16]. Secondly, as a tourist hub in central China, Wuhan has a large floating population. According to statistics, there were approximately 2,243,700 floating population who lived in Wuhan for more than six months in 2018 [17]. These floating populations may have a history of exposure to SARS-CoV-2, which may contribute to the spread of the virus. The Wuhan Huanan Seafood Wholesale Market, considered an early epicentre of the COVID-19 pandemic, is located in the centre of Wuhan. As one of the largest seafood wholesale markets in central China, about 10,000 people visit the market daily [18].

The timing of the outbreak of the COVID-19 pandemic is the Chinese traditional festival Spring Festival. On this particular festival time, most people will choose to celebrate the Chinese New Year in their hometowns or during their travels. In China, this is the most significant population movement of the year [15]. Residents and tourists make billions of trips across China during the Spring Festival to celebrate the Chinese New Year [19]. During this period, about 5 million people left Wuhan to go all over the country and even the world [20]. This huge number of populations might include asymptomatic infections and SARS-CoV-2 infections in the incubation period. Furthermore, there is a great possibility that the virus has spread to other provinces and cities in China and other countries. This has brought significant challenges to containing the epidemic.

3.2 Transportation Network

Another factor influencing the virus spread is that Wuhan has a well-connected transportation network. Wuhan is one of the most important transportation hubs in China [15]. It has three railway stations, an international airport and an important inland port at the confluence of the Yangtze and Han rivers [21]. Zhang, Zhang and Wang also pointed out that it is also very convenient to travel from Wuhan to other important cities in China, such as Beijing, Shanghai, Guangzhou and Hong Kong [21]. This well-developed transportation became the cause of the outbreak and accelerated the spread of the virus in Wuhan and the world during the outbreak of COVID-19. The study found a significant positive correlation between the frequency of flights, trains and buses from Wuhan and the daily and number of COVID-19 cases in other cities [15]. In addition, Huanan Market is less than 600 meters away from Hankou Railway Station [17] As a public place with a large flow of people that can arrive in the whole country, the railway station may consider one of the factors to increase the risk of SARS-CoV-2 transmission in Wuhan.

3.3 Lack of Preparedness

The rapid spread of SARS-CoV-2 caught many countries and cities off guard. Even though Wuhan, as one of the bustling cities in China, has apparent deficiencies in the sudden outbreak and emergency public health plans. During the COVID-19 pandemic, China's healthcare system struggled to provide adequate care to all infected patients, as well as those with other illnesses [22]. The medical system in Wuhan was overwhelmed by the rising number of confirmed and suspected cases and the spread of the virus [23]. There are only two infectious disease hospitals in Wuhan, with 1,399 beds [24]. However, as the number of infected people continued to rise, Wuhan had a severe shortage of hospital beds. During the lockdown of Wuhan, there were massive shortages of medical resources, food and basic daily necessities due to poor preparation. The healthcare system is under enormous strain due to understaffing [23]. During the epidemic, there was also a severe shortage of personal protective equipment for healthcare workers, facing higher infection risks [22]. Sun et al. also discussed that ventilators, medical surgical masks, essential medicines and equipment are insufficient to meet the needs of hospitals and society [22]. Under the heavy workload, some medical staff have developed mental health problems such as depression, anxiety and insomnia [23]. Food shortages are also an issue that has arisen during the COVID-19 outbreak. With residential communities in Wuhan completely lockdown, people are unable to leave their homes or apartments, let alone go directly to the shops and supermarkets [25]. Zhong et al. mentioned the food shortages due to COVID-19 in Wuhan; as many as 95% of surveyed households reported food insecurity, including a decline in the quality and variety of food [25].

3.4 Delayed Response

The Disease Prevention and Control agency was unable to diagnose and prevent the spread of SARS-CoV-2 at an early stage because China failed to recognize the virus' contagiousness and severity [22]. Some believe China was simply slow to respond to the outbreak. However, a small number of people believe that China concealed the discovery of the virus in the early stages of the outbreak. Gostin presented the earliest cases may date back to early December 2019, but China chose to hide the real information about the virus and did not report outbreaks to the WHO [26]. In the beginning, the Chinese government's concealment of information about the epidemic caused delays in the public's access to information about the epidemic, which exacerbated the negative impact of the epidemic [27]. Moreover, delays in reporting outbreaks are due to the inflexibility of the system. In the event of a new outbreak, the outbreak data needs to be reported up the hierarchy and needs to be rigorously analysed at every level [22]. Disease information needs to report and review from the sentinel hospital, community, prefecture, provincial, national, and Ministry of health level by level, and then send the feedback from the Ministry of health to the sentinel hospital step by step [22]. Cumbersome reporting and feedback steps result in prevention and intervention

information for outbreaks not being disseminated to hospitals and communities promptly and rapidly. As a result, it has led to the spread of the virus worldwide.

3.5 Poor Primary Health Care System

Although China's healthcare system has undergone tremendous development in recent decades, it is still necessary to address the existing issues. China is now focusing on the quality of medical services and ignores public health [28]. From the perspective of Wuhan's loss of COVID-19 prevention and control, the public health systems in Wuhan and even China still lack attention to primary health care. China's primary health institutions, which is community hospitals, should have played the role of the goalkeeper in the outbreak of the epidemic, inhibiting the large scale spread of the virus [22]. However, in many large cities, such as Wuhan, many patients are accustomed to bypassing primary health care institutions and go directly to the third tertiary hospital for treatment [29]. There are large differences in service quality of primary health care institutions and hospitals in China. Most doctors and nurses in primary health care institutions have low educational levels, poor diagnosis ability, and limited knowledge of infectious diseases [28]. This has led the public to distrust and refuse to go to community hospitals. These deficiencies lead to overload at the outpatient clinic of tertiary hospitals and the cross infections might to occur in patients during the clinic and waiting time, especially at the beginning, substantially exacerbated SARS-COV-2 infection in Wuhan [29]. While it is true that the COVID-19 pandemic originated in Wuhan, it was not inevitable or unavoidable. The outbreak could have been contained if appropriate measures were taken in a timely manner. However, the Wuhan's authorities were slow to recognize the severity of the outbreak and failed to take prompt action to contain it. This allowed the virus to spread rapidly, both within China and to other countries. One of the main issues is that China's primary health care system still has some distribution and infrastructure problems. Even after China responded quickly and later realised the severity of the virus, the shortage of medical equipment and supplies and trained medical personnel have become problematic in China's response to the pandemic. These shortfalls make it difficult to provide adequate care for COVID-19 patients and put pressure on the entire healthcare system. There are also very few professionals in the primary health care system. Some experts need more epidemiological knowledge [28]. The government should provide continuous skill improvement and professional development training for junior health workers. This ensures that they have the skills and knowledge required for high quality care to increase the trust of patients [30]. At the same time, the government needs to provide basic primary care and infectious disease knowledge and skills to specialists in tertiary hospitals so that the number of medical staff can be increased to reduce the pressure on medical care during an epidemic. Outbreaks of SARS-CoV-2 might not be inevitable if they can be reported early in the pandemic and preventive interventions developed to respond.

4. Special Intervention in the City of Wuhan

Even though many problems were exposed in the early days of Wuhan's response to COVID-19, the government still did its best to control the number of infections and treat patients aggressively. Due to the lack of hospital beds for patients infected with COVID-19 in the City of Wuhan, the convention centres, stadiums, and other large public place have been converted into 'wards' for patients, also known as 'Fangcang hospitals' [22]. These places were rapidly built and admitted on a large scale to isolate people with mild to moderate COVID-19 infections and symptoms, while providing medical care, disease monitoring, food, shelter and social activities [31]. The medical staff might also lead the patients to perform health exercises or simple physical activities to enrich their lives and move their bodies during the isolation period. These 'hospitals' relieve the burden on the healthcare system and free up hospital beds for patients with severe symptoms. This played an indelible role in allowing effective control of the spread of the virus and treatment at the later stage of the pandemic.

5. Conclusion

These factors might make a pandemic inevitable and unavoidable. Both virus awareness and well-prepared public health emergency planning can be critical factors in reducing virus transmission and outbreaks. But the government in Wuhan did not prepare for this sudden pandemic. Although some have criticized the initial response of the Chinese government to the outbreak in Wuhan, it is essential to note that SARS-CoV-2 is a new and complex virus. Its characteristics include high infectivity, long incubation period and asymptomatic infection might result in many countries and health organizations have struggled to respond quickly and effectively to its spread. Considering all the factors of SARS-CoV-2 and the city of Wuhan, it is worth noting that many countries and regions around the world have faced significant challenges in controlling the spread of COVID-19, and attributing blame to a single city or location is not necessarily productive. Instead, it is crucial to focus on understanding the factors that contribute to the spread of the infectious virus and developing effective strategies to mitigate their impact.

References

1. CDC. COVID-19 and Your Health [Internet]. Centers for Disease Control and Prevention. (2020) [cited 2023 Feb 4]. Available from: <https://www.cdc.gov/coronavirus/2019-ncov/your-health/about-covid-19/basics-covid-19.html>
2. WHO Coronavirus (COVID-19) Dashboard [Internet]. [cited 2023 Feb 7]. Available from: <https://covid19.who.int>
3. Worobey M, Levy JI, Serrano LM, Crits-Christoph A, Pekar JE, Goldstein SA, et al. The Huanan Seafood Wholesale Market in Wuhan was the early epicenter of the COVID-19 pandemic. *Science*.: abp8715.
4. Hu B, Guo H, Zhou P, Shi ZL. Characteristics of SARS-CoV-2 and COVID-19. *Nat Rev Microbiol*. (2021);19(3):141–54.
5. Coronavirus [Internet]. [cited 2023 Feb 4]. Available from: <https://www.who.int/health-topics/coronavirus>
6. Meyerowitz EA, Richterman A, Gandhi RT, Sax PE. Transmission of SARS-CoV-2: A Review of Viral, Host, and Environmental Factors. *Ann Intern Med*. (2020); M20-5008.
7. Asadi S, Bouvier N, Wexler AS, Ristenpart WD. The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? *Aerosol Sci Technol*. (2020);1–4.
8. Kumar A, Singh R, Kaur J, Pandey S, Sharma V, Thakur L, et al. Wuhan to World: The COVID-19 Pandemic. *Frontiers in Cellular and Infection Microbiology* [Internet]. (2021) [cited 2023 Feb 9];11. Available from: <https://www.frontiersin.org/articles/10.3389/fcimb.2021.596201>
9. Oran DP, Topol EJ. Prevalence of Asymptomatic SARS-CoV-2 Infection. *Ann Intern Med*. (2020);173(5):362–7.
10. Gandhi M, Yokoe DS, Havlir DV. Asymptomatic Transmission, the Achilles' Heel of Current Strategies to Control Covid-19. *New England Journal of Medicine*. (2020);382(22):2158–60.
11. Johansson MA, Quandelacy TM, Kada S, Prasad PV, Steele M, Brooks JT, et al. SARS-CoV-2 Transmission From People Without COVID-19 Symptoms. *JAMA Network Open*. (2021);4(1): e2035057.
12. Wassie GT, Azene AG, Bantie GM, Dessie G, Aragaw AM. Incubation Period of Severe Acute Respiratory Syndrome Novel Coronavirus 2 that Causes Coronavirus Disease 2019: A Systematic Review and Meta-Analysis. *Curr Ther Res Clin Exp*. (2020); 93: 100607.
13. Heiser T. If you're fully vaccinated, wait a few days after a COVID-19 exposure before getting tested [Internet]. Norton Healthcare. (2021) [cited 2023 Feb 9]. Available from: <https://nortonhealthcare.com/news/how-long-after-exposure-to-test-positive-for-covid/>
14. Wu Y, Kang L, Guo Z, Liu J, Liu M, Liang W. Incubation Period of COVID-19 Caused by Unique SARS-CoV-2 Strains: A Systematic Review and Meta-analysis. *JAMA Network Open*. (2022);5(8): e2228008.
15. Zheng R, Xu Y, Wang W, Ning G, Bi Y. Spatial transmission of COVID-19 via public and private transportation in China. *Travel Med Infect Dis*. (2020); 34:101626.
16. Wuhan Population 2023 [Internet]. [cited 2023 Feb 9]. Available from: <https://worldpopulationreview.com/world-cities/wuhan-population>

17. Fan C, Liu L, Guo W, Yang A, Ye C, Jilili M, et al. Prediction of Epidemic Spread of the 2019 Novel Coronavirus Driven by Spring Festival Transportation in China: A Population-Based Study. *Int J Environ Res Public Health*. (2020);17(5):1679.
18. Courtier-Orgogozo V, de Ribera FA. SARS-CoV-2 infection at the Huanan seafood market. *Environmental Research*. (2022); 214:113702.
19. Du Z, Wang L, Cauchemez S, Xu X, Wang X, Cowling BJ, et al. Risk for Transportation of Coronavirus Disease from Wuhan to Other Cities in China. *Emerg Infect Dis*. (2020);26(5):1049–52.
20. Chen ZL, Zhang Q, Lu Y, Guo ZM, Zhang X, Zhang WJ, et al. Distribution of the COVID-19 epidemic and correlation with population emigration from Wuhan, China. *Chinese Medical Journal*. (2020);133(9):1044.
21. Zhang Y, Zhang A, Wang J. Exploring the roles of high-speed train, air and coach services in the spread of COVID-19 in China. *Transp Policy (Oxf)*. (2020); 94:34–42.
22. Sun S, Xie Z, Yu K, Jiang B, Zheng S, Pan X. COVID-19 and healthcare system in China: challenges and progression for a sustainable future. *Globalization and Health*. (2021);17(1):14.
23. Liu Q, Luo D, Haase JE, Guo Q, Wang XQ, Liu S, et al. The experiences of health-care providers during the COVID-19 crisis in China: a qualitative study. *The Lancet Global Health*. (2020);8(6): e790–8.
24. Liu L. Sustainable COVID-19 Mitigation: Wuhan Lockdowns, Health Inequities, and Patient Evacuation. *Int J Health Policy Manag*. (2020);9(10):415–8.
25. Zhong T, Crush J, Si Z, Scott S. Emergency food supplies and food security in Wuhan and Nanjing, China, during the COVID-19 pandemic: Evidence from a field survey. *Dev Policy Rev*. (2022);40(3): e12575.
26. Gostin LO. The Coronavirus Pandemic 1 Year On—What Went Wrong? *JAMA*. (2021);325(12):1132–3.
27. Zhang L, Li H, Chen K. Effective Risk Communication for Public Health Emergency: Reflection on the COVID-19 (2019-nCoV) Outbreak in Wuhan, China. *Healthcare*. (2020);8(1):64.
28. Xing C, Zhang R. COVID-19 in China: Responses, Challenges and Implications for the Health System. *Healthcare*. (2021);9(1):82.
29. Tan X, Liu C, Wu H. Reflections on China’s primary care response to COVID-19: roles, limitations and implications. *Prim Health Care Res Dev*. (2022); 23: e46.
30. Nelson L. China’s Healthcare System: Addressing Capacity Shortfalls before and after COVID-19.
31. Chen S, Zhang Z, Yang J, Wang J, Zhai X, Bärnighausen T, et al. Fangcang shelter hospitals: a novel concept for responding to public health emergencies. *The Lancet*. (2020);395(10232):1305–14.