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Review of the risk factors for SARS-CoV-2 transmission

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Abstract

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic, which has lasted for nearly a year, has made people deeply aware of the strong transmissibility and pathogenicity of SARS-CoV-2 since its outbreak in December 2019. By December 2020, SARS-CoV-2 had infected over 65 million people globally, resulting in more than 1 million deaths. At present, the exact animal origin of SARS-CoV-2 remains unclear and antiviral vaccines are now undergoing clinical trials. Although the social order of human life is gradually returning to normal, new confirmed cases continue to appear worldwide, and the majority of cases are sporadic due to environmental factors and lax self-protective consciousness. This article provides the latest understanding of the epidemiology and risk factors of nosocomial and community transmission of SARS-CoV-2, as well as strategies to diminish the risk of transmission. We believe that our review will help the public correctly understand and cope with SARS-CoV-2.

Key Words: SARS-CoV-2; COVID-19; Transmission; Infection; Nosocomial; Risk

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Core Tip: The coronavirus disease 2019 pandemic has not only placed a heavy burden on the health system but has also led to significant sociological, psychological, and economic adverse effects globally. A comprehensive understanding is needed of the risk factors of transmission of severe acute respiratory syndrome coronavirus 2 and strategies to diminish this risk. At the same time, people need to act in a socially responsible and cohesive manner, thus creating a common living space with a low risk of infection.

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is known for its high infectivity and pathogenicity, has lasted for nearly a year since the outbreak in the city of Wuhan, China at the end of 2019^[1,2]. As of December 8, 2020, SARS-CoV-2 had infected 65872391 patients with 1523656 deaths (2.3% mortality rate) worldwide, with the largest number of cases in the United States (14191298 cases with 276503 deaths, 4.1% mortality rate)^[3]. Unlike the two highly pathogenic coronaviruses previously identified, namely SARS-CoV in 2002-2003 and Middle East respiratory syndrome coronavirus (MERS-CoV) in 2012^[4,5], SARS-CoV-2 not only far exceeds them in the number of confirmed people with infection but has also overwhelmingly expanded to nearly 230 countries and regions in terms of spatial spread, posing great threats and challenges to social public health and medical systems^[6].

In this review, we share the latest understanding of the epidemiology and risk factors of nosocomial and community transmission of SARS-CoV-2, and discuss the clinical characteristics of COVID-19, as well as strategies to diminish the risk of transmission and stress related to the pandemic.

EMERGENCE AND SPREAD OF SARS-COV-2

In late December 2019, a cluster of unidentified pneumonia cases occurred in the Huanan Seafood Wholesale Market in Wuhan, Hubei Province, China where live wild animal sales often occur before shutdown^[6,7]. By January 7, 2020, the novel coronavirus was isolated from bronchoalveolar lavage fluid samples of confirmed infected pneumonia patients, and was later officially named SARS-CoV-2 by the International Committee on Taxonomy of Viruses on February 11, 2020^[8]. At the same time, the World Health Organization (WHO) named this disease caused by SARS-CoV-2, COVID-19. Shockingly, in the following month, SARS-CoV-2 spread fast from Wuhan to Hubei province and even the whole country, and the number of confirmed and suspected cases increased by hundreds of thousands every day^[9]. Due to the severity of the outbreak, on January 30, 2020, the WHO announced that the pandemic caused by SARS-CoV-2 is a public health emergency of international concern (PHEIC), which is the sixth time since the International Health Regulations (2005) took effect on June 15, 2007^[10]. On March 11, 2020, the WHO officially declared the COVID-19 outbreak a global pandemic. An outline of the PHEIC announced by the WHO in the recent decade is listed in [Table 1](#).

As the initial center of the SARS-CoV-2 outbreak, Wuhan combines multiple factors conducive to the emergence and spread of the virus such as convenient transportation facilities, more than 84 universities, and a floating population of 5 million. Another factor that cannot be ignored is that the outbreak coincided with the Spring Festival holiday at the end of the year, which is the largest annual population movement. A large number of people such as tourists, students, and migrants moved and consequently accelerated the spread of SARS-CoV-2. Most infections occurred as a result of person-to-person spread and the imported cases caused by these passengers leaving Wuhan *via* public transportation were responsible for the spread of SARS-

Table 1 Public health emergency of international concern announced by the World Health Organization

Public health PHEIC announced by WHO
H1N1 influenza pandemic in 2009
Polio eradication in 2014
Ebola virus outbreak in West Africa in 2014
Zika virus outbreaks in 2016
Ebola outbreak in the Democratic Republic of Congo in 2018
SARS-CoV-2 outbreak in 2020

H1N1: Influenza A; PHEIC: Public health emergency of international concern; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2; WHO: World Health Organization.

CoV-2, which may explain the subsequent spread and outbreak of the international COVID-19 epidemic.

Although the number of newly confirmed cases in China has shown a downward trend since February 2020, the international epidemic situation is not optimistic. Italy is the second country that was hit hard by SARS-CoV-2 after China, and SARS-CoV-2 quickly spread across Europe and North America^[11]. In the face of the spreading epidemic, many countries, such as those in Asia, have taken various measures to control its development including social isolation, closing public places, and non-essential outdoor activities. However, the effectiveness of these non-drug interventions varies from region to region. The overloaded medical system and the irrational and blind behavior of some people have significantly limited the government's power and/or effectiveness in the battle against the epidemic^[12,13]. In addition, although Africa has made significant progress in preventing and controlling infectious diseases since the Ebola outbreak in 2014-2016, the SARS-CoV-2 epidemic remains a huge challenge due to limited resources^[14].

SOURCE OF SARS-COV-2 INFECTION

Previous studies have reported a close connection between wild animals and some confirmed cases, and it is presumed that SARS-CoV-2 may have been first transmitted from a wild animal to humans, after which it spread widely from person to person^[15,16]. Since the SARS epidemic in 2003, extensive epidemiological investigations have shown that bats carry multiple coronaviruses that have the potential to infect humans^[17-19]. The bat-derived coronavirus RaTG13 from the *Rhinolophus affinis* bat from Yunnan Province, China, shares up to 96.2% similarity of the gene sequence with SARS-CoV-2^[20].

Pangolins are also thought to be a possible host for SARS-CoV-2. Earlier on October 24, 2019, Liu and colleagues first isolated SARS-like coronavirus from two dead Malayan pangolins illegally imported into Guangdong province, illustrating the diversity of pangolin virus using viral metagenomics analysis^[21]. Subsequently, strong identity to SARS-CoV-2 in the receptor-binding domain was found from the pangolin lung samples^[22]. In addition, researchers from the South China Agricultural University in Guangzhou proposed that pangolin could be the most likely intermediate host for SARS-CoV-2 based on the finding that a virus strain 99% similar to SARS-CoV-2 in genome sequence was isolated from pangolin^[23].

Researchers have also tried to find possible intermediate hosts for SARS-CoV-2 in common animals such as cats, dogs, and pigs^[24]. However, the available data have not led to identification of the specific source and intermediate host of SARS-CoV-2 transmission. Although patients diagnosed with COVID-19 are thought to be the main source of infection, all of these findings may help trace the origin and probable intermediate hosts of SARS-CoV-2 to block interspecies transmission.

PATHOGENESIS OF SARS-COV-2

SARS-CoV-2 targets the respiratory system as the main mechanism for attacking the

human body, and the patient can gradually progress to severe pneumonia, secondary infection, and even multiple organ failure^[15]. SARS-CoV-2 binds to the same receptor, angiotensin-converting enzyme 2 (ACE2), for cell entry as SARS-CoV^[25,26]. Due to the high expression of ACE2 in nasal epithelial cells, SARS-CoV-2 enters epithelial cells through ACE2 in the upper respiratory tract and then begins to replicate and move into the lower respiratory tract of the lung^[27]. Breakdown of the lung epithelial-endothelial barrier caused by viral replication drives a series of immune responses in the body^[28]. The release of pro-inflammatory cytokines, such as interleukin 6 and tumor necrosis factor alpha, may stimulate the increase of reactive oxygen species in various organs or tissues, including vascular endothelial cells^[29,30] and the respiratory system^[31,32]. On the other hand, oxidative stress during respiratory viral infection may also exacerbate cytokine storms^[33]. Cytokine storms are considered to be a major killer in patients with severe COVID-19 infection, and higher levels of pro-inflammatory cytokines have been found in these patients, indicating that they are closely related to disease severity^[34-36]. Of note, compared to elderly patients, cytokine storms may be more severe in young patients because of their more developed immune system^[37], which may explain why some otherwise very healthy young adults have died from COVID-19.

Histological examination has revealed that the typical pathological features in patients with severe COVID-19 are mainly located in the lungs, which are markedly similar to the pathological features of SARS and MERS^[38,39]. The lung tissues mainly have bilateral diffuse alveolar damage, extensive interstitial fibrosis, hyaline membrane formation, and inflammatory infiltration of lymphocytes, indicating acute respiratory distress syndrome^[40]. Recently, pathological findings of the extra-pulmonary organs have been reported including myocardial interstitial macrophage infiltration^[41], lymphocyte reduction, and macrophage aggregation in spleen and hilar lymph nodes^[42].

NON-SPECIFIC CLINICAL FEATURES OF COVID-19

Apparently, to make a definitive diagnosis of COVID-19, a good understanding is needed about the occurrence and development of its clinical manifestations and the abnormalities of imaging and laboratory tests. The initial screening for SARS-CoV-2 usually begins at fever clinics, with fever, cough and shortness of breath being the most important symptoms in the majority of confirmed patients^[43]. Other respiratory symptoms include expectoration, stuffy nose, and sore throat^[44]. In addition, the appearance of patchy shadows or ground-glass shadows on chest X-rays or lung computed tomography scans is also a hallmark of COVID-19. However, similar to SARS and MERS, respiratory symptoms are not unique clinical manifestations of COVID-19, while some extra-pulmonary symptoms including myalgia, headache, fatigue and anorexia are common and most patients with COVID-19 have gastrointestinal symptoms, such as abdominal pain, nausea, vomiting, and diarrhea^[16,45-47]. Actually, gastrointestinal symptoms, while not specific, are common in confirmed COVID-19 patients, and some patients only present with gastrointestinal discomfort without any respiratory abnormalities^[48,49]. Clinically, these non-specific symptoms in the early outbreak of epidemic may be difficult to distinguish from many other common infectious diseases, especially in the winter and spring when influenza is highly prevalent. Some infected patients thought they had just caught a cold and did not pay enough attention at the early stage of symptoms, and thus no self-quarantine or other protective procedures such as mask wearing were exercised, indicating that everyone who came into close contact with them including family members, social service workers, and medical staff were at high risk of infection.

As an indicator of the transmissibility of a virus, the basic reproduction number (R_0) of SARS-CoV-2 differs between research groups and is updated as available and accurate information is increasing. Recently, the mean value of R_0 was estimated to be 3.28, with a median of 2.79, indicating the high infectiousness of SARS-CoV-2, which is consistent with the ongoing epidemic^[50]. Furthermore, available evidence indicates that the median incubation period of SARS-CoV-2 is about 5 d, and 97.5% of patients develop symptoms within 11.5 d of infection^[51]. Pre-symptomatic patients who tested positive prior to the onset of symptoms may unconsciously carry the virus into the surrounding environment during incubation time, thus accelerating the transmission cycle of SARS-CoV-2.

RISK FACTORS FOR POOR OUTCOMES

Based on many clinical studies, elderly COVID-19 patients with pre-existing chronic diseases are more prone to serious complications, progressively developing organ failure and even death^[52,53]. As a result of relatively weaker immunity, the elders with chronic diseases are more prone to various bacterial and viral infections such as influenza, bacterial pneumonia, and even premature death^[54,55]. Compared to patients without diabetes, COVID-19 patients with diabetes alone prior to the onset of illness have higher inflammation responses, which may be associated with the exacerbated progression and poor outcomes^[56]. Apart from advanced age and comorbidity, laboratory examination indexes including elevated neutrophil count, blood urea nitrogen (BUN), lactate dehydrogenase (LDH), and D-dimer all reportedly result in the poor prognosis of COVID-19^[57-59]. Our previous study^[60] reported that 34 patients with COVID-19 were unintentionally scheduled for elective surgeries during the incubation period, of which 15 (44.1%) patients were transferred to the intensive care unit (ICU) for further treatment and 7 patients (20.5%) ultimately died after admission to the ICU. Another cohort study of 1128 patients from 24 countries showed that more than half of patients with perioperative SARS-CoV-2 infection had postoperative pulmonary complications and accounted for 81.7% of all deaths^[61]. Putting aside the risk factors for poor outcomes mentioned above, the tissue trauma and inflammatory response caused by anesthesia, surgery and other invasive measures (transfusion of blood products, use of extracorporeal circulation) may further weaken the immunity of patients, which affect the disease progression and even increase mortality^[62-65]. Moreover, administration of high-dose corticosteroids during hospitalization may indicate worsening of the condition in patients with severe COVID-19^[66].

Taken together, risk factors for poor prognosis (severity and death) of patients with COVID-19 are as follows: older age, male sex, comorbidity (hypertension, respiratory system disease, diabetes, cardiovascular and cerebrovascular disease), surgery-related trauma and laboratory biochemical indicators such as high D-dimer, increased neutrophil count, BUN, LDH and plasmin(ogen)^[67].

NOSOCOMIAL TRANSMISSION

In the early stages of the epidemic in China, 57 (41.3%) of 138 patients in a single center were suspected of nosocomial transmission, including 17 (12.3%) hospitalized patients and 40 (29%) medical staff^[45]. A prospective cohort study from London reported that the rate of nosocomial infection among frontline medical staff was up to 44%^[68]. Because SARS-CoV-2 can be transmitted through normal breathing, coughing, sneezing, talking and surface contact^[69], when interacting with patients in the hospital, especially in situations such as endotracheal intubation, manual ventilation before endotracheal intubation and bronchoscopy, medical staff and hospital cleaners are at higher risk of exposure to the virus and can transmit SARS-CoV-2 to patients with low immunity^[70]. Compared to doctors working in fever clinics, doctors in other departments are less vigilant and have lower levels of personal protective equipment (PPE), and thus have a high chance of being infected. Patients with normal body temperature, who visited different outpatient clinics for non-respiratory symptoms, greatly drove the nosocomial spread of SARS-CoV-2.

Even a SARS-CoV-2-infected patient with mild upper respiratory symptoms can cause extensive environmental contamination. In a COVID-19 ward, SARS-CoV-2 was detected in samples from 13 (87%) of 15 room sites (including air outlet fans) and 3 (60%) of 5 toilet sites (toilet bowl, sink, and door handle) before routine cleaning^[71]. A study investigating the environmental contamination of SARS-CoV-2 in hospitals showed that self-service printers (20.0%), desktops/keyboards (16.8%) and doorknobs (16.0%) were the most contaminated in-hospital facilities, while hand sanitizer dispensers (20.3%) and gloves (15.4%) were the most contaminated in terms of PPE^[72]. Another retrospective study evaluating risk factors for COVID-19 showed that poor hand hygiene after contact with a confirmed patient made the hands of healthcare workers a life-threatening tool to transmit SARS-CoV-2^[73]. Under enormous pressure from the large number of confirmed cases, the shortage of protective equipment and irregular prevention measures may accelerate the spread of SARS-CoV-2 in hospitals.

COMMUNITY TRANSMISSION

Early confirmed COVID-19 cases were found to have a clear history of exposure to Huanan Seafood Wholesale Market, and it is not difficult to speculate that community transmission may have occurred first and subsequent human-to-human transmission contributed to the progress of the epidemic and even the outbreak of SARS-CoV-2^[74]. Notably, clusters of outbreaks in family and other communities such as office buildings or shopping malls is a frightening phenomenon of SARS-CoV-2 infection^[75-77]. The high transmissibility of SARS-CoV-2 may be linked to the viability and stability of the coronavirus in different environments, which is often overlooked by the general public. **Table 2** summarizes the duration of survival for SARS-CoV-2, SARS-CoV, and MERS-CoV on the surfaces of different materials^[78-83]. SARS-CoV-2 can survive for several hours in aerosols and up to days on surfaces of plastic, stainless steel, copper and cardboard at temperature of 21-23 °C and 40% relative humidity^[78]. In comparison, MERS-CoV remained viable on different surfaces for 48 h at 20 °C and 40% relative humidity^[80], while SARS-CoV can survive for 2 wk after drying, remaining viable for up to 5 d under similar conditions^[79]. The prolonged survival of these coronaviruses under various conditions increases the likelihood of contact and fomites transmission. Due to frequent contact with public facilities such as elevators and relatively closed spaces, SARS-CoV-2 can easily be transmitted in settings that have a defined population, especially in densely populated areas with poor sanitation^[81-84].

EFFECT OF SOCIOECONOMIC STATUS ON THE TRANSMISSION

It is widely believed that people of lower socioeconomic status are in much worse physical health condition and at higher risk of premature mortality than those of higher socioeconomic status, mostly because most people with high socioeconomic status have a good educational background, basic health knowledge, and better healthcare services^[85,86]. Looking back at 2020 under the ravages of SARS-CoV-2, it is not hard to see that demographic and socioeconomic factors affect the spread of the virus. Data from the United States suggest that population density, gender ratio, low income and predominantly black communities are highly correlated with SARS-CoV-2-positive rates^[87,88]. To date, as a country with a large population, India has the second highest number of infections after the United States. In India, the undeveloped health care system and the lack of medical supplies including respiratory ventilators and protective equipment have weakened the government's leadership and ability to respond to SARS-CoV-2^[89,90]. Strict social distancing measures and the lockdown of workplaces decrease the social labor force and put people at risk of unemployment, so vulnerable groups with financial difficulties may neglect to comply with physical distance measures because they need to work to survive, thereby increasing the risk of SARS-CoV-2 transmission^[91]. Conversely, a heavy medical burden has also led to severe economic recession and crisis. The rise in healthcare costs and drug prices have increased barriers for people with chronic and complex diseases, making this group of people at high risk of infection and disease progression during COVID-19 outbreaks. Additionally, the rapid progress of COVID-19 has exposed a serious problem that the majority of the world lack basic health care knowledge when facing infectious disease, for which they paid a painful price for their irrational and blind behavior, even in developed European countries^[92,93].

STRATEGIES TO REDUCE THE RISK OF TRANSMISSION

At the peak of the epidemic, non-drug interventions, such as maintaining social distance and wearing masks, have shown considerable effectiveness. Although the outbreak gradually subsided in China, given the uncontrolled epidemic and current lack of confirmed effective treatments and vaccines for SARS-CoV-2, continuous prevention still depends heavily on compliance with public health measures (**Table 3**). First, more attention should be paid to the hand hygiene of staff in hospital and they should be urged to clean their hands in the right way at the right time. Optimized hospital and community management system are urgently needed to centralize the management of confirmed and suspected cases, thereby reducing the spread of the virus to healthy people^[94,95]. All medical staff involved in the management should be equipped with standard PPE including gloves, gowns, eye shields, and N95

Table 2 Survival of severe acute respiratory syndrome coronavirus, Middle East respiratory syndrome coronavirus, and severe acute respiratory syndrome coronavirus 2 on various materials

Ref.	van Doremalen <i>et al</i> ^[78]	van Doremalen <i>et al</i> ^[80]	Chan <i>et al</i> ^[79]	Rabenau <i>et al</i> ^[82]	Lai <i>et al</i> ^[83]	Duan <i>et al</i> ^[81]
Year	2020	2013	2011	2005	2005	2003
Location	United States	United States	Hong Kong, China	Germany	Hong Kong, China	China
Virus	SARS-CoV-2, SARS-CoV	MERS-CoV	SARS-CoV	SARS-CoV	SARS-CoV	SARS-CoV
Load applied (TCID ₅₀)	SARS-CoV-2: 10 ^{5.25} in aerosols, SARS-CoV: 10 ^{6.75-7.00} in aerosols	10 ⁶ in aerosols, 10 ⁵ on steel and plastic	10 ⁵ on plastic	NA	Dilution solution (10 ² -10 ⁴)	10 ⁶
Substrate (s)	Aerosols, plastic, stainless steel, copper, cardboard	Aerosols, steel, plastic	Plastic	Polystyrene petri dish	Paper, disposable gowns, cotton gowns	Wood board, glass, mosaic, metal, cloth, paper, filter paper, plastic
Temperature/RH	21-23 °C/40%	Variable	Variable	Room temperature (21-25 °C)	Room temperature	Room temperature
Viability	Viable SARS-CoV-2 detected after 3 h in aerosols, no viable SARS-CoV-2 detected after 4 h on copper and 24 h on cardboard, stable after 72 h on plastic and stainless steel; no viable SARS-CoV detected after 8 h on copper and 8 h on cardboard	The viability of MERS-CoV decreased 7% at 40% RH and 89% at 70% RH in aerosols; Viable MERS-CoV tested after 48 h at 20 °C/40% RH, 8 h at 30 °C/80% RH and 24 h at 30 °C/30% RH	SARS-CoV survived for 5 d at 22-25 °C relative humidity of 40%-50% with only 1 log ₁₀ loss of titer and was viable for more than 20 d; SARS-CoV was more stable at relatively low temperatures (28 °C <i>vs</i> 38 °C) and humidity (80%-89% <i>vs</i> > 95%)	SARS-CoV survived for more than 6 d and retained its infectivity for up to 9 d	SARS-CoV survived no more than 5 min to 24 h on paper, 1 h to 2 d on disposable clothing, and 5 min to 24 h on cotton clothing	SARS-CoV survived for > 72 h on the surfaces of eight materials, and > 120 h on metal, cloth and filter paper
Reduction in infectious titer (TCID ₅₀)	SARS-CoV-2: from 10 ^{3.5} to 10 ^{2.7} in aerosols, from 10 ^{3.7} to 10 ^{0.6} after 72 h on plastic, from 10 ^{3.7} to 10 ^{0.6} after 48 h on stainless steel; SARS-CoV: from 10 ^{4.3} to 10 ^{3.5} in aerosols, from 10 ^{3.4} to 10 ^{0.7} after 72 h on plastic, from 10 ^{3.6} to 10 ^{0.6} after 48 h on stainless steel	NA	The reduction in infectious titer was similar in solution compared with virus dried on surfaces	NA	NA	NA
Half-life	SARS-CoV-2 :1.1 h in aerosols, 6.8 h on plastic, 5.6 h on stainless steel, 0.8 h on copper, 3.5 h on cardboard; SARS-CoV :1.2 h in aerosols, 7.6 h on plastic, 4.2 h on stainless steel, 1.5 h on copper, 0.6 h on cardboard	The half-life of MERS-CoV ranged from 0.6 to 1 h on steel and from 0.4 to 1 h on plastic	NA	NA	NA	NA

MERS-CoV: Middle East respiratory syndrome coronavirus; RH: Relative humidity; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2.

respirators to protect themselves, especially when directly exposed to high-risk invasive operations such as airway suctioning, endotracheal intubation and throat swabs^[96-98]. Then, theoretically, the threshold for admission to hospital should be higher than usual to reduce the risk of potential in-hospital transmission, especially for surgical patients. For hospitalized patients, the number of caregivers should be limited to 1-2 persons and non-essential visits should be avoided. Moreover, it is recommended that network media be used for non-contact follow-up after discharge^[99]. Enhanced infection control measures should be implemented strictly in

Table 3 Measures to prevent the transmission of severe acute respiratory syndrome coronavirus 2**Measures to prevent SARS-CoV-2 transmission**

Strengthen the environmental hygiene of the medical sector and the personal hygiene of medical staff
Standardize the management procedures for confirmed and suspected cases to reduce nosocomial transmission
Equip health-care workers with PPE to protect their safety
Strictly assess hospitalization criteria and limit nonessential visits
Increase public awareness and education on infectious diseases and measures to prevent the spread of diseases on an individual basis
Enhance supervision and management of the flow of people in public places to reduce large-scale gatherings

PPE: Personal protective equipment; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2.

public facilities, which are effective in controlling clusters outbreak. Finally, in the fight against SARS-CoV-2, apart from the external factors, self-resistance and personal immunity are essential to defeat this global pandemic^[100,101]. Individuals must actively implement and comply with control strategies issued by sanitary authorities to strengthen personal protection including wearing a mask, developing a healthy lifestyle, and social distancing.

CONCLUSION

The prevalence of SARS-CoV in 2003, MERS-CoV in 2012 and now SARS-CoV-2 suggests that coronaviruses in the natural environment may pose a lasting threat to humans, for which people worldwide have paid a huge cost, and it remains unknown whether this will be the last. In view of the current pandemic, it is reasonably speculated that SARS-CoV-2, as an emerging coronavirus, is likely to establish a stable environment suitable for living in organisms and coexist with humans for a long time^[102]. With the gradual recovery of normal work, study and medical care, it is essential to accurately estimate the contribution of asymptomatic carriers to SARS-CoV-2 transmission^[103,104]. Meanwhile, although it is not clear whether SARS-CoV-2 transmission will be seasonal or year-round^[105], the strong sense of crisis aroused by this pandemic would promote the normalization of prevention and control measures.

Despite a great deal of studies trying to find the origin of SARS-CoV-2 and its molecular mechanism, our understanding of it is just the tip of the iceberg and several important questions on the epidemiology, pathogenesis and treatment of SARS-CoV-2 still remain unanswered (Table 4)^[106-108]. Although SARSCoV-2 might be transmitted from bats *via* unknown intermediate hosts to infect humans, whether or not currently available existing animal models can accurately reflect the process of human infection with the virus remains to be determined^[109]. In addition, a series of major medical, economic and psychological problems caused by the rapid spread of SARS-CoV-2 need the cooperation of all mankind to solve^[110,111]. Relevant health authorities should maintain surveillance, release the latest situation of the epidemic timely and respond scientifically.

Table 4 Unanswered questions about severe acute respiratory syndrome coronavirus 2

Unanswered questions about SARS-CoV-2

Where does SARS-CoV-2 really originated from and how does it affect humans?
Will the spread of SARS-CoV-2 be a seasonal outbreak?
Why is the prevalence of SARS-CoV-2 infection lower in children than in adults?
Is the infectivity of a patient positively related to the severity of the disease?
What is the proportion of asymptomatic carriers worldwide and what role do they play in transmission?
What is the probability that a cured patient is re-infected with SARS-CoV-2?
How does SARS-CoV-2 invade other organs than the lung?
Can animal experiments find out the specific pathogenesis of SARS-CoV-2 infection?
How long will it take to develop effective vaccine or medicine against SARS-CoV-2?

SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2.

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