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Prevention and control of coronavirus disease 2019 (COVID-19) in public places^{*}

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ABSTRACT

Public places favor the transmission of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) due to dense population, large personal mobility, and higher contact opportunities. In order to protect the health of general public in operating public places during COVID-19 pandemic, this study proposed general precautions and control strategies from perspective of operation management, social distancing, cleaning and disinfection, and personal protection. In addition, with regard of risk level, specific precautions and control strategies were proposed for living service places, outdoor places, and confined places. The comprehensive application of above recommendations could effectively interrupt the spread of COVID-19, and protect the health of general public in public places.

This study proposed general and specific precautions and control strategies in public places during COVID-19, and suggested further improvement of pandemic response.

1. Introduction

Since December 2019, some unexplained cases of pneumonia were found in Wuhan, China (Wuhan Municipal Health Co, 2019). The pneumonia was subsequently named as coronavirus disease 2019 (COVID-19) and declared a pandemic by World Health Organization (WHO) on March 11, 2020 (World Health Organization, 2020). As of September 13, 2021, over 224 million confirmed cases of COVID-19, including just under 4.6 million deaths, were reported to WHO (World Health Organization, 2020b). The rapid spread of SARS-CoV-2 in the globe is closely related with its strong contagiousness. The basic reproductive number (R_0) of SARS-CoV-2 in the community setting is estimated to range from 1.4 to 3.9 (LiPei et al., 2020; WuLeung and Leung, 2020), which is greater than that of seasonal influenza (0.9–2.1) and MERS (0.29–1.44), and close to SARS (~3) (LiGuan et al., 2020). Also, the SARS-CoV-2 can survive at least 3 hours in the aerosol, on copper surface for at least 4 hours, carton surface for 24 hours, stainless steel and plastic (polypropylene) surface for 2–3 days (WanWu et al., 2014). However, it is sensitive to ultraviolet rays and heat, and can be effectively inactivated by heating at 56 °C for 30 min and lipid solvents such as ether, 75 % ethanol, chlorine containing disinfectant, peroxyacetic acid and chloroform except chlorhexidine (National Health Commissio, 2019a). The main transmission routes of COVID-19 include droplet transmission and contact transmission; in relatively confined environment, long-term exposure to high concentrations of aerosols has the possibility of aerosol transmission (National Health Commissio, 2019b). The droplet transmission mainly occurs when the distance to infection source is short. Without external interference, the transmission distance of droplets is generally within 2 m. Contact transmission has been reported via shaking hands, sharing foods, participating conferences and other forms in different settings (ChanYuan et al., 2020).

SARS-CoV-2 transmission from contaminated dry surfaces has been postulated including self-inoculation of mucous membranes of the nose, eyes or mouth (OtterDonskey et al., 2016; DowellSimmerman et al., 2004; GellerVarbanov and Duval, 2012). It is also confirmed by the fact of environmental contamination after a confirmed case touched object surfaces in the isolation room (OngTan et al., 2020). With continuously updated and deepened knowledge of SARS-CoV-2, more evidences have been found to prove the possibility of aerosol transmission in a relatively confined environment (National Health Commissio, 2019b; LuoZheng et al., 2020). SARS-CoV-2 was detected in the air of the hospital intensive care unit with a detection rate of 3.57 % (JiangLiu et al., 2020). Guo et al. found that SARS-CoV-2 was not only widely distributed in the air, but also on object surfaces in both an intensive care unit (ICU) and a general COVID-19 ward (GW) with a transmission distance up to 4 m¹⁷. On the Diamond Princess cruise ship, transmission was ongoing during the 14-day quarantine; after the end of 14-day quarantine, over 90 COVID-19 cases were confirmed across many different cabins (MoriartyPlucinski et al., 2020; Descriptive epidemiology, 2020). Moreover, SARS-CoV-2 has also been detected in gastrointestinal tract, saliva, urine, and feces, which implies a risk of fecal oral transmission (Mino-dierCharrel et al., 2015).

Also, SARS-CoV-2, like all other virus, change over time. Nine notable variants of SARS-CoV-2 have been found since so far (World Health Organization, 2021). Some of these variants are more transmissible (such as delta), able to spread at lower exposure levels which means higher danger in public places. Unfortunately, the vaccine is also less protective for some variants. Although how many variations will appear in the future remains unknown, there is no doubt that the variants will be a huge hamper for the prevention of COVID-19. Public places are places to which the public or a substantial group of the public has access, including schools, hospitals, office buildings, shops, etc. With

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dense population, large personal mobility, and higher contact opportunities, public places favor the transmission of SARS-CoV-2. The strong contagiousness of COVID-19 also significantly increases the risks in public places. A COVID-19 cluster was reported to be caused by direct contact between shop assistants and tourists at a shop in Singapore (PungChiew et al., 2020). Clusters of COVID-19 cases in shopping malls and high-speed railway workers were reported in China (WuLi et al., 2020; ZhangSu et al., 2020). In South Korea, the rapid spread of COVID-19 has been attributed to one case linked to a superspreading event from church services in Daegu, leading to more than 3900 secondary cases (ShimTariq et al., 2020). In Singapore, an international conference hosted at the end of January was found to be the source of a number of infections. As of February 9th, 2020, 7 attendees had tested positive for the virus in Singapore, Malaysia, South Korea, and the UK (Hodcroft, 2020).

COVID-19 vaccines are already widely available in a number of countries. Safe and effective vaccines are useful for the control of COVID-19, but for the foreseeable future it is still essential to appropriately implement precautions such as personal protective equipment (PPE) use, hand hygiene, good ventilation, social distancing and avoiding crowds. Therefore, development of an effective response strategy in public places is in urgent need to protect the general public in addition to maintain the normal operation of the society and reduce the economic losses to the maximum extent during the pandemic.

2. General precautions and control strategies

In order to effectively respond to COVID-19 pandemic in public places, complete closure might be considered as a foolproof measure to prevent and control COVID-19, but it would trigger tremendous economic losses. Moreover, some of public places must keep open in order to maintain basic social operation and satisfy basic living needs. In order to find a solution to this dilemma, this study explored the feasibility of applying the non-pharmaceutical interventions (NPIs) to public places and provided suggestions from perspectives of operation management, social distancing, cleaning and disinfection, and personal protection measures for different types of public places during COVID-19 pandemic.

2.1. Operation management

Robust operation management system contributes to reduction of COVID-19 infection risk. Owners and administrators should be primarily responsible for prevention and control of COVID-19 in public places. It is recommended for them to develop emergency plan, collect health information of employees, reasonably arrange the shifts, and improve precaution compliance of both employees and customers through videos, posters, brochures, etc. Also, increasing vaccination rates among employees is necessary. People with fever, cough, or other symptoms are encouraged to timely seek for medical treatment and those who with abnormal body temperature should not be allowed to enter public places (Centers for Disease Contr, 2020a; Centers for Disease Contr, 2020b; Centers for Disease Contr, 2020c). For people inside public places, those who with sudden suspected symptoms should be isolated temporarily in the emergency area in time. Natural ventilation is recommended in premise of ensuring indoor thermal comfort degree by opening doors or windows 2–3 times a day with duration of 0.5 h each time. Only clean air conditioning and ventilation systems could be used, and the open cooling tower, filter screen, filter, purifier, air outlet, air handling unit, surface cooler, heater (humidifier), condensate pan and other parts should be disinfected or replaced regularly. If the air conditioning and ventilation system in public places is not equipped with disinfection device, it is recommended to close the return air system (Centers for Disease Contr, 2020d). Wastes are suggested be classified and disposed in time in designated waste treatment areas and the temporary waste storage area should be kept clean and disinfected at least once a day

(QuallsLevitt et al., 2017). If confirmed cases were found in a public place, it is necessary to carry out terminal disinfection under the direction of local CDCs, and the air conditioning ventilation system should be shut down immediately.

2.2. Social distancing

Maintaining social distancing can minimize exposure and interrupt SARS-CoV-2 transmission by reducing droplet and contact transmissions as well as potential aerosol transmission that occurs within 3–6 ft (Centers for Disease Contr, 2019; FiorinoAllocca et al., 2020). WHO and some countries have been calling for more research on the effectiveness, timing, and optimal implementation of social distancing measures in different community settings since 2017 (Department of Health, 2017; World Health Organization, 2017). Social distancing measures in public places include closure of parts of public places, encouragement of mobile payment, teleworking at home, increasing physical space between workers at the worksite, staggering work schedules, decreasing social contacts in the workplace, etc. (Centers for Disease Contr, 2020e; FongGao et al., 2020). Mass gatherings such as group meals, centralized meetings, and exhibitions, should be avoided. It is suggested to stagger meal time or have meal alone and maintain physical distance when communicating with others. For department store, pharmacies, restaurants, etc., it is suggested to stop in-store services and provide home delivery via online order or curbside pickup. At the same time, some services in nursing rooms, playground for children and indoor entertainment places should be suspended. If the closure is not applicable, facilities must be carefully disinfected before opening the public places.

2.3. Cleaning and disinfection

Deficiency of effective cleaning and disinfection measures will lead to the spread of SARS-CoV-2 in public places. It is reported that SARS-CoV-2 had been detected on surfaces in the isolation area with suspected patients (GuoWang et al., 2020), and a large number of studies also confirmed that hands or gloves of healthcare workers may be contaminated by contacting surfaces contaminated by SARS-CoV-2 (SaitohSato et al., 2020; GonDancer et al., 2020) suggesting the necessity of surface cleaning and disinfection. The cleaning and disinfection should be conducted at least once a day before open and recorded. The frequency could be adjusted properly in congregated public places. Spraying or wiping disinfection is recommended using disinfectant containing 250 mg/L–500 mg/L available chlorine or wipes containing alcohol or other effective disinfectant. For the surface of objects frequently contacted (service desk, elevator button, handrail, door handle, shopping cart, public table and chair, etc.), the cleaning and disinfection could be strengthened. The sanitary ware could be disinfected using disinfectant containing 500 mg/L chlorine by wiping (WeiRen, 2020). It should be pointed out that after disinfection, surfaces must be rinsed or wiped with clean water and dried before use (Notice of the guidelines, 2020).

2.4. Personal protection

Timely vaccination is always one of the most effective pathway to curb the spread of infectious disease. Rational use of masks in congregated or relatively confined public places in high risk area is recommended because the effectiveness of mask have already been confirmed in healthcare settings by healthcare workers as part of droplet precautions when taking care for patients with respiratory infections (FengShen et al., 2020). As evidence suggests, COVID-19 could be transmitted before symptom onset, the transmission in public places might be reduced if general public could wear a mask. Specific personnel should also be arranged to remind people to wear masks before entering public places and wash hands after going back home. In addition, it is very important to implement hand hygiene measures. During work,

employees and employers should wash their hands frequently or use effective alcohol containing hand sanitizer. Under certain conditions, it is also acceptable to use chlorine containing or hydrogen peroxide containing hand disinfectants. In case of visible pollutants, it is recommended to wash hands using running water before using hand sanitizer and avoid touching eyes with hands or gloves. It is also required to ensure the normal operation of hand washing facilities, and provide hand sanitizer at the information desk and cash register. The employees in congregated public places without adequate ventilation are suggested to be equipped with masks, gloves, and goggles in premise of sufficient supply of personal protective equipment (PEE).

3. Specific precautions and control strategies

According to functions and services provided, public places could be classified as living service places, outdoor places, and confined places. The specific risk adjusted precautions and control measures of SARS-CoV-2 in these three types of operating public places with different risk levels are summarized in Table 1. Living service places provide daily necessities for the general public. In these places, the surface of objects frequently contacted (such as service desk, elevator button, handrail, door handle, shopping cart) could be easily polluted by SARS-CoV-2 and

Table 1
Risk adjusted precautions and control strategies of SARS-CoV-2 in operating public places.

Type	Public places	Risk level	Suggestion
Living service places	Shops, groceries, supermarkets, bars, restaurants, hotels	Low and medium	Operation management: reduce mass gatherings such as sales, adequate ventilation, health monitoring, set up the emergency area Social distancing: flow density control, mobile payment Cleaning and disinfection: regular clean and disinfect before open Personal protection: mask use, hand hygiene
		High	Shorten business hours except for above measures
Outdoor places	Flea markets, parks, beaches	Low and medium	Operation management: reduce mass gatherings, adequate ventilation, health monitoring, set up the emergency area Social distancing: flow density control, mobile payment Cleaning and disinfection: regular clean and disinfect object surfaces Personal protection: mask use, hand hygiene
		High	Shorten business hours except for above measures
Confined places	Elevators, restrooms	Low and medium	Operation management: health monitoring Social distancing: maintain social distance as far as possible Cleaning and disinfection: regularly clean and disinfect the surface of elevator keys, side walls, floors, etc. Personal protection: mask use, hand hygiene
		High	Increase the frequency of cleaning and disinfection 3 times to 6 times except for above measures

become the media of contact transmission. The frequent communication between customers and salesman in different scenarios, such as paying, selecting merchandises, and seeking for assistance would also increase the infection risk of COVID-19 by droplet transmission (RotheSchunk et al., 2020). The return air system favors air transmission of SARS-CoV-2 via central air conditioning (LuGu et al., 2020), especially when confirmed or suspected cases speak, breath, cough, or sneeze in public places without effective Personal Protective Equipment (PPE).

Outdoor places mainly include flea markets, parks, beaches, etc., which are located outdoor with ideal ventilation. In these places, activities such as cookout, camping, and bonfire party would easily cause mass gatherings. The latest research results showed that walking, running, or riding bicycles outside might generate a vacuum or a slip-stream and infect another person behind via respiratory droplets (Simulation research shows, 2020). Moreover, in places like flea markets, the close contact between sellers and buyers might also increase the risk. Therefore, the essential protection and control measures should be aiming at reducing mass gatherings and maintaining social distancing.

Confined places mainly include relatively enclosed environment such as elevator and restroom. In these places, the essential protection and control measures should be aiming at blocking contact transmission by strengthening cleaning and disinfection of object surfaces, especially when confirmed or suspected cases come into these places or touch object surfaces in these places. In addition, prevention of potential aerosol transmission should be taken into consideration.

In order to further improve the efficiency of prevention and control measures. A risk and setting based precaution strategy were proposed.

3.1. Low risk area

3.1.1. Place protection

① Before operation, we should reserve the epidemic prevention materials such as masks and disinfectants, formulate the emergency plan, set up the emergency disposal area, implement the main responsibility of the unit, and strengthen the personnel training.

② Establish a health monitoring system for employees, register the health status of employees every day, and seek medical treatment in time when the temperature exceeds 37.3 °C.

③ Strengthen ventilation. Every 2–3 hours, open the doors and windows for ventilation for 20–30 minutes. If the central air conditioner is used, check whether the equipment is normal before opening; Whether there is short circuit between the fresh air outlet and the exhaust outlet (for example, the fresh air outlet is above and the exhaust outlet is below), and the horizontal distance between the fresh air outlet and the cooling tower and other pollution sources should not be less than 10 m; Clean the cooling tower and keep the fresh air outlet clean; In the process of operation, the maximum fresh air volume is used, the sanitation management of cooling water and condensate water is strengthened, and the air supply outlet and other equipment and components are cleaned, disinfected or replaced every month.

④ Do a good job of cleaning and disinfection of elevator, public toilet and other public equipment and facilities, door handle and other high-frequency contact surface. Every 6 hours, use chlorine disinfectant with effective chlorine concentration of 250–500mg/L to wipe and disinfect once. The public articles and appliances in guest rooms should be “one for each guest, one for each use and one for disinfection”.

⑤ Keep the lobby, elevator entrance, front desk, guest room corridor and other areas clean and tidy, set up special collection bins for discarded masks, and clean the garbage once a day.

⑥ Public toilets should be equipped with hand sanitizer (or soap) to ensure the normal operation of water supply facilities such as faucets. If possible, quick drying hand disinfectant or inductive hand disinfection equipment can be equipped in the lobby, elevator entrance and front desk.

⑦ “One meter line” should be set to remind customers to keep a safe distance. Non direct contact payment methods such as online ticket

purchase and code scanning payment are encouraged.

③ Water supply and drainage facilities should be improved in the market. Open sewer should be set on the ground to keep the sewer unblocked. There should be no sewage, ponding or sediment on the ground and in the open sewer. The ground flushing faucet and disinfection facilities shall be provided to facilitate the flushing and disinfection of sewage.

④ The publicity of health knowledge was strengthened through posters, electronic screens and billboards.

3.1.2. Personal protection

③ The staff should wear disposable medical mask or medical surgical mask and replace it every 4–6 hours. Replace the mask when it is wet or dirty.

In addition, customers should strengthen hand hygiene. Pay attention to personal hygiene, conduct hand hygiene in time, avoid touching mouth, eyes and nose with unclean hands, cover mouth and nose with paper towel or elbow and arm when sneezing or coughing.

3.2. Medium and high risk areas

In addition to the prevention and control measures in low-risk areas, the following measures should also be taken:

3.2.1. Place protection

At the entrance, add temperature measuring equipment, the temperature is not more than 37.3 °C personnel can enter. If the high efficiency and above level filter device is used in the central air conditioning ventilation system (pipeline) or air conditioning box, or the disinfection device (ultraviolet lamp) is installed, the return air can be turned down, otherwise the return air needs to be turned off. If there is air mixing structure, the air mixing component of central air conditioning ventilation system should be closed before opening, and the air mixing mode should be stopped. Every three hours, use chlorine containing disinfectant with effective chlorine concentration of 250–500mg/L to wipe and disinfect the surfaces of public equipment and facilities such as elevators, public toilets and high-frequency contact objects such as door handles. Reduce gathering activities such as dinner, training, meeting and entertainment. Shorten the business hours, control the number of customers, and prohibit promotional and exhibition activities. No dining in restaurants. Reasonably arrange the duty shift of employees, shorten the working time from 8 hours to 6 hours, or take a rotation rest every 4 hours for 30 minutes to 1 hour. According to one third of the elevator load to control the elevator personnel density.

3.2.2. Personal protection

Workers should wear medical protective masks and change them every 4–6 hours. Keep a proper distance from customers, prevent direct contact. Clean and disinfect in time after working. Customers should wear disposable medical masks or medical surgical masks. Disinfection should be carried out in time after going out.

3.2.3. Emergency response

When COVID-19 cases occur, the pollution assessment should be conducted before the terminal disinfection under the guidance of the local centers for disease control and prevention. When there is no visible pollutant, spray or wipe with chlorine containing disinfectant with effective chlorine of 1000 mg/L or chlorine dioxide disinfectant of 500 mg/L, wipe with clean water after 30 min, or disinfect with other effective disinfectants according to the product instructions. When there are visible pollutants, the disposable water absorbent material should be used to cover and disinfect with chlorine containing disinfectant of 5000 mg/L-10000 mg/L available chlorine (or dry disinfection towel that can achieve high level disinfection). After the pollutants are completely removed, the chlorine containing disinfectant of 1000 mg/L available chlorine or chlorine dioxide disinfectant of 500 mg/L available chlorine

should be used for spraying or wiping disinfection. After 30 minutes of action, the water should be wiped clean, or use other effective disinfectants to disinfect according to the product instructions. The central air conditioning and ventilation system in the area where the case was located was closed, and the air conditioning and ventilation system was disinfected first, and then cleaned. It can be used again after passing the hygienic evaluation.

4. Conclusions

This study proposed general precautions and control strategies from perspectives of operation management, social distancing, cleaning and disinfection, and personal protection. In addition, with regard of risk level, specific precautions and control strategies were proposed for living service places, outdoor places, and confined places. The general and specific strategies proposed in this study would be beneficial to reduce the spread of SARS-CoV-2 or other pathogens and protect health and safety of people in public places. However, the pandemic response could be further improved following principles as follows:

- (1) Increasing vaccination rates around the world. At intra-/international level, exchanges and cooperation are recommended among different countries and international organizations in order to take concerted actions to development vaccines and drugs for COVID-19 and prevent and control infectious disease outbreaks. In addition, the government needs to formulate strategies to reopen public places and promote coordination among different regions.
- (2) At departmental level, close cooperation of multiple departments and cross-integration of multiple disciplines, such as finance, public health, education, market regulation, and environmental protection, are encouraged, so as to formulate feasible and targeted technical guidelines of infectious disease prevention and control.
- (3) At local level, local government should adjust precautions to guide public places strengthening operation management, maintaining social distancing, implementing cleaning and disinfection, and encouraging appropriate personal protective measures, etc.
- (4) The compliance of general public in public places should be further improved via health knowledge popularization. A poster or electronica billboard could be set up in a conspicuous position to remind people to comply with precautions. Furthermore, the popularization pattern could be further explored to fill the gap between professional knowledge and public perception.

Contributions

LP, and LW had the idea for and designed the study. LP and JW contributed equally to this work. LP, JW, DY, and LW drafted the paper, and all authors critically revised the manuscript and gave final approval for the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to any part of the work are appropriately investigated and resolved.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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