Control of Spread of Coronavirus Disease

Gentle Sunder Shrestha and Saurabh Pradhan

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that causes the disease COVID-19 has been declared as pandemic by the World Health Organization (WHO) and has spread to more than 200 countries around the world. Despite stringent and desperate measures to control the spread, such as whole country lockdown for weeks to months, more than 14 million people have been affected till date, and more than hundred thousands of people are getting infected each day [1]. The medical world was unprepared for the unprecedented threat that has caused the loss of so many lives and long-lasting repercussions on worldwide economy. However, with knowledge about the disease gradually increasing, measures to stop the spread are being implemented. In this chapter we discuss about what the current evidences recommend regarding prevention of spread of SARS-CoV-2.

14.1 Transmission of Coronavirus

The mode of transmission has major implications in prevention of spread of a disease. The close genetic similarity of SARS-CoV-2 to bat coronaviruses suggests a zoonotic origin with a spillover to humans in late 2019. Human-to-human transmission was confirmed on January 2020 [2], but confusion remains regarding the mode of transmission, with droplets and aerosols both being attributed.

Viral particles can spread through encapsulation in globs of mucus, saliva, and water. Dissemination of such particles may depend on various factors but primarily on the size of the globs. Bigger globs fall to the ground within a short distance before they can evaporate, forming droplets [3]. Smaller globs evaporate and form
respiratory nuclei or aerosols, which can suspend in the air and drift farther away than the droplets. Though the distinction between droplets and aerosols is a gray area, there is general agreement that particles with a diameter of 5 μm or less are aerosols, whereas particles of a diameter more than 5 μm would be droplets [4].

Droplet transmission means infection can be acquired through direct contact of infected secretions, or indirectly through fomites. If SARS-CoV-2 is primarily spread by respiratory droplets, wearing a medical mask, face shield, or keeping 6 ft. distance in between individuals should be adequate to prevent transmission. If, however, SARS-CoV-2 is carried by aerosols, then such methods would not be sufficient, and an N95 respirator would be required.

Investigators have demonstrated that speaking, coughing, and even breathing can produce aerosols [5]. Experimental data have suggested that virus particles of COVID-19 can remain suspended in the air for 3 h [6]. However, the experimental conditions did not replicate a human cough and may not be generalizable to exposures that health-care workers typically encounter. Demonstrating that speaking and coughing can generate aerosols or that it is possible to recover viral RNA from air, however, does not prove aerosol-based transmission as information regarding transmissions in general populations do not match with long-range aerosol-based transmission. The reproduction number for COVID-19 is estimated to be about 2.5, meaning that each person with COVID-19 infected an average of 2–3 other people. This reproduction number is similar to influenza and quite different from that of viruses that are well-known to spread via aerosols such as measles, which has a reproduction number closer to 18 [5].

Evidence suggesting airborne transmission is therefore inconsistent, and thus guidelines also differ in recommendations regarding the type of precautions. However there is a consensus that airborne transmission might occur during aerosol-generating procedures (AGP). AGP are medical procedures that create aerosols in addition to those that the patient creates spontaneously [7]. There is poor agreement as to what constitutes an AGP. However, the most consistent association across multiple studies has been identified with tracheal intubation with a pooled odds ratio of 6.6 [8]. Again it must be emphasized that intubation presents a period of prolonged and closed contact with the upper respiratory tract of the patient and that the patients requiring intubation are much sicker indicating a higher viral load. Furthermore these data have been extrapolated from SARS and not SARS-CoV-2.

14.2 Infection Prevention and Control Practices in COVID-19

Apart from usual standard practices involving infection prevention and control (IPC), there are several additional protocols that may be applied in the period of a pandemic to minimize the exposure to COVID-19.
14.2.1 Screening and Triage

Screening for COVID-19 can be performed even before entry to the health-care center with the help of telemedicine. Before scheduling appointments, communication via telephone or video call can be done to assess the symptoms, screen for COVID-19, determine whether the patient requires hospital visit or not, and recommend necessary measures if visit is not required. Many patients with COVID-19 can be managed from home, but they need to be educated about alarming signs and symptoms and told to report urgently if they experience any such manifestations. For those who require additional evaluation, referral to a clinic or health center dedicated to the management of patients with confirmed or presumptive COVID-19 is preferable. In case of unavailability of such facilities, referral to any other center is needed where necessary precautions should be pre-arranged [9].

At the hospital entry, all patients need to be screened for COVID-19 before entering the hospital premises. A high index of suspicion is required. A triage station such as fever clinic can be established, where a compulsory temperature check (infrared thermometers help avoid contact with the patient) and an assessment of symptoms and contact history should be performed. Immediate isolation in a separate area should be performed if there is suspicion of COVID-19. Visitors should be restricted and also screened for exposure and assessed for symptoms and temperature measured [9].

14.2.2 Source Control

Screening cannot identify those who are in their presymptomatic phase of illness or are asymptomatic, which can account for a large proportion of cases (around 40% documented in published literature [10] and may be up to 99% in some places as observed from unpublished sources [11]). Therefore source control becomes a primary modality in prevention of spread of the disease. Hand hygiene is of prime importance, and alcohol-based hand rubs (ABHR) or a sink for hand washing with soap and water should be available at the entry and at places where contact may take place. An ABHR consisting of 60–95% alcohol is preferred over soap and water due to evidence of better compliance. However when hands are visibly soiled, soap and water should be used for at least 20 s [9].

Facemask should be worn by all individuals. The benefit of universal masking has been evidenced in a study done in Mass General Brigham, the largest healthcare system in Massachusetts, with more than 75,000 employees. After the universal masking policy was adopted, the proportion of health-care personnel testing positive declined from 14.7 to 11.5% with an average decrease of 0.49% per day [12]. Proper respiratory etiquette should be ensured. A recent systematic review and
meta-analysis reported that transmission of viruses was lower with physical distancing of 1 m or more, compared with a distance of less than 1 m (pooled adjusted odds ratio of 0.18, 95% CI 0.09–0.38), and the protection was increased as distance was lengthened [13]. We support the practice of physical distancing of at least 1 m. Signs that remind people of the precautionary measures should be placed at various areas. Specific seating arrangements and placing markers for those standing in queue are helpful in ensuring physical distancing [9].

14.2.3 Universal Testing

Depending on guidance from health departments, both local and state, testing availability, and how quickly results are available, facilities can consider implementing pre-admission or pre-procedure diagnostic testing [9]. The results can help taking decisions about rescheduling elective procedures or the need for additional transmission-based precautions during patient care. However, false negative results can occur, especially during the incubation period.

14.2.4 Engineering Controls

Engineering controls can be optimized to decrease the potential spread of COVID-19 from infected individuals. Physical barriers and dedicated pathways to guide symptomatic patients through triage areas, remote triage facilities for patient intake areas, outdoor assessment and triage stations for patients with respiratory symptoms, and improving indoor air quality (directionality, filtration, exchange rate, maintenance) in all shared spaces are some of the techniques to help contain infection [9].

14.2.5 Administrative Measures

Policies should be made available whereby the identification of suspected or confirmed COVID-19 is reported within the hospital staffs to promote situational awareness and implementation of necessary precautions. Reporting to necessary public health authorities and designating specific persons responsible for communication is important. COVID-19 patients should be cared for by dedicated healthcare personnel, and thus staffing needs and modifications need to be determined [9]. Prior to designating staffs for the care of COVID-19 patients, adequate training regarding infection prevention techniques, which include donning and doffing methods of PPE, should be provided. An IPC program run by a dedicated team would be ideal to achieve the highest level of effectiveness in controlling the outbreak to achieve the highest level of effectiveness in the response to the outbreak [14].


**14.2.6 Patient Placement**

Patients with suspected or confirmed SARS-CoV-2 infection should be segregated in a different section of the hospital, away from other patients. Ideally they should be admitted in a single room with a dedicated bathroom. Confirmed patients can be cohorted together if single rooms are not available. Transport and movement of the patient outside of the room should be limited. If necessary, a facemask should be applied to the patient during transport [9].

Airborne infection isolation rooms (AIIRs) should be reserved for patients undergoing aerosol-generating procedures. These rooms are single-patient rooms with anteroom and a dedicated bathroom. To avoid the spread of infected aerosols, a negative pressure is maintained in the room by having the exhaust air flow rate exceed the supply air flow rate [15]. Staff protection inside the AIIR is ensured by air flow patterns within the room. A pressure difference of at least 2.5 Pa and ventilation with at least 6 air changes per hour (ACH) for existing rooms and 12 ACH for new rooms are recommended [16]. However guidelines may vary with some countries suggesting a pressure difference of 30 Pa [17]. In addition to general ventilation, other source control methods such as high-efficiency particulate air (HEPA) filters are required. HEPA filters can capture 99.97% of 0.3 mm particles and are important to remove infectious aerosols before they are dispersed throughout the room or from air that is re-circulated [15]. An anteroom ensures additional protection by creating two door barriers and causing dilution of any aerosols that may escape when AIIR door is opened [15].

**14.2.7 Personal Protective Equipment**

Apart from standard precautions, all HCP involved in direct care of the patient or handling of their body fluids needs to put on personal protective equipment (PPE). PPE may have to be applied as a universal precaution if there is moderate to substantial community transmission, in which case a facemask and eye protection becomes necessary, with N95 respirator applied for aerosol-generating procedures. Hand hygiene should be performed prior to donning and during doffing of PPE as well as according to the WHO “5 moments of hand hygiene.”

- **Respirator or Facemask:** WHO states that a facemask is adequate for general care [14], whereas Centers for Disease Control and Prevention (CDC) guidelines prefer an N95 respirator or equivalent or higher-level respirator but acknowledge a facemask as an acceptable alternative if a respirator is unavailable [9]. For aerosol-generating procedures, a respirator is recommended. Respirators protect against airborne infection, gases, and vapors, whereas facemask only protects against droplets. There is lack of studies comparing the efficacy of respirators versus facemasks in preventing SARS-CoV-2 transmission, but several reports
suggest great reduction in transmission with standard and contact precautions, with respirators being reserved for aerosol-generating procedures. [18, 19]

- Respirators need to be certified by the Centers for Disease Control and Prevention (CDC)/National Institute for Occupational Safety and health (NIOSH) and are classified as filtering facepiece respirators (CDC) or powered air-purifying respirators (PAPRs). FFPs and facemasks are single use and should be discarded appropriately. However during scarcity, N95 respirator can be reused, with a study showing no loss of efficacy up to three times after disinfection [20].
- Prior to use, FFPs need to be fit tested.
- **Eye Protection:** Eye protection device includes either goggles or a face shield. Goggles only cover the eyes, but a face shield covers the eyes as well as the front and sides of the face. Eye protection needs to be compatible with the respirator used as to avoid any interference with positioning [9].
- **Gloves:** Clean, non-sterile gloves are required to be worn upon entry into the care area. The number of layers of gloves to be worn has not been specified by guidelines, and the practice seems to vary among institutions and health-care centers [9].
- **Gowns and Coveralls:** A gown is a protective wear that is worn from the front and thus prevents frontal contamination only with partial neck to knee protection. Coverall is designed to protect the entire body and thus enables 360° of protection from contagion. We prefer a coverall when available as it ensures higher protection; however it is cumbersome to wear and work for longer time periods, and doffing is also more difficult than a gown.

### 14.2.8 Specific Precautions for Aerosol-Generating Procedures

As discussed earlier, there are certain medical procedures that are considered aerosol generating. The list includes but is not limited to:

- Endotracheal intubation and extubation
- Non-invasive ventilation
- Bag valve mask ventilation
- Cardiopulmonary resuscitation
- Bronchoscopy
- Open suctioning of airways
- Nebulization
- High-flow nasal cannula
- Tracheostomy

Apart from tracheal intubation, there is no robust data to suggest that the procedures mentioned above are aerosol-generating procedures or that there is a higher probability of transmission associated with them. However considering a safety-first approach, it would be reasonable to avoid these procedures if possible and use other alternatives. For example, metered dose inhalers may be used instead of
nebulizers for inhalational therapy of drugs. If performed, however, the following precautions should be mandated. These include wearing an N95 or equivalent or higher-level respirator, eye protection, gloves, and a gown; performing the procedure in an AIIR; restricting the number of health-care personnel in the room to only those essential for patient care; and disinfecting the room surfaces promptly.

14.2.9 Environmental Infection Control

Environmental infection control is a crucial step in mitigating disease transmission, and many hospitals have implemented protocols to disinfect areas where COVID-19 patients have been cared for. Such protocols include the use of dedicated medical equipment or disposable equipment if possible, management of laundry, food service utensils, and medical waste in accordance to routine protocols; and environmental cleaning and disinfection. The importance of environmental disinfection was illustrated in a study from Singapore. Viral RNA was detected on almost all surfaces tested such as handles, light switches, bed, and handrails, when disinfection was not performed; however no viral RNA was detected after cleaning the rooms with sodium dichloroisocyanurate [22].

Prior to disinfection, cleaning of contaminated surfaces is essential to reduce the infective load and remove organic matter that would impede proper disinfection by rapidly inactivating the chemicals. Cleaning should progress from the least soiled (cleanest) to the most soiled (dirtiest) areas, and from the higher to lower levels [19].

Disinfectant solutions must be prepared and used according to the manufacturer’s recommendations for volume and contact time as the concentration and contact time are critical for effective surface disinfection, which is considered as $>3 \log_{10}$ reduction of human coronavirus [23]. Hypochlorite-based products are most commonly used in this. They form hypochlorous acid (HOCl) when dissolved in water, which is the primary antimicrobial compound. The recommendation of 0.1% (1000 ppm) will inactivate the vast majority of pathogens that may be present in the health-care setting. However, for blood and body fluids large spills (i.e., more than about 10 mL), a concentration of 0.5% (5000 ppm) is recommended [24]. Ethanol 70–90% and hydrogen peroxide $>0.5\%$ can also be used as disinfectants. The routine application of disinfectant by spraying or fogging to environmental spaces, whether indoor or outdoor, is not effective, and is thus not recommended [21]. Personnel performing cleaning and disinfection must don appropriate PPE, including an N95 or equivalent or higher-level respirator, while cleaning AIIR.

Adjunctive disinfection methods, such as ultraviolet (UV) light, have been approved as non-touch techniques. These technologies developed for use in healthcare settings are used during terminal cleaning (cleaning a room after a patient has been discharged or transferred), and it must be emphasized that these techniques only supplement but do not replace the manual cleaning techniques. There are also safety concerns, since UV light fixtures can produce sunburn-like skin reactions and eye damage as well as generate ozone if strict safety measures are not utilized in their installation and maintenance [25].
14.2.10 Quarantine

Quarantine is a method of separating persons who may have been exposed to an infectious agent but have not become ill from those who have not been exposed to the agent. It is considered one of the oldest and most effective tools of controlling communicable disease outbreaks [26, 27]. A mathematical model done on the spread of COVID-19 demonstrated that pandemic could not be controlled without strict quarantine [28].

Individuals who may have had prolonged close contact with someone with confirmed COVID-19 patients should undergo quarantine for 14 days after their last contact [29]. A contact has been defined as having face-to-face contact within 1 m for >15 min (CDC extends the perimeter to within 6 ft.), staying in the same close environment as a COVID-19 patient (including sharing a workplace, classroom, or household or being at the same gathering) for any amount of time, or travelling in close proximity with (i.e., within 1 m separation from) a COVID-19 patient in any kind of conveyance [9, 14]. For health-care personnel, providing direct care or performing aerosol-generating procedures without using proper personal protective equipment or having unprotected direct contact with infectious secretions or excretions of the person with confirmed COVID-19 is also considered a close contact [30].

It is difficult to determine the time period from when the patient may have been infectious. The exposure window is considered to start from 2 days before symptom onset up to the time when infection precautions can be discontinued (will be discussed below). For asymptomatic patients, it is even more challenging. Patients with COVID-19 should be considered infectious 2 days after their exposure; when exact time of exposure cannot be determined, it may be reasonable to consider 2 days prior to the positive test result [31].

Testing asymptomatic individuals after an exposure may give false negatives, and therefore it is a better practice to continue precautions for the total time period irrespective of the test result.

14.2.11 Discontinuing Infection Precautions

For patients with COVID-19, the decision to discontinue precautions may be time based (symptom based) or test based [32]. Choosing one strategy over another should be determined on a case-by-case basis, since each strategy has theoretic limitations. Available data indicate that persons with mild to moderate COVID-19 remain infectious no longer than 10 days after symptom onset, but persons with more severe to critical illness or severe immunocompromise likely remain infectious no longer than 20 days after symptom onset [33]. Although recovered persons can continue to shed detectable SARS-CoV-2 RNA in upper respiratory specimens for up to 3 months after illness onset, the concentrations in their secretions are considerably lower than during illness, and thus infectiousness is unlikely [34]. Therefore current guidelines recommend time-based strategy, i.e., infection control precautions may be discontinued when the following criteria are met [31]:

- The patient has been afebrile for at least 24 hours.
- The patient’s oxygen saturation is equal to or greater than 95%.
- The patient is not using supplemental oxygen.
- The patient has no respiratory symptoms.
- The patient has received their last dose of antiviral medication (if applicable) and has been off it for at least 48 hours.
- The patient has been asymptomatic for 72 hours.
- The patient has been afebrile for at least 72 hours.
- The patient has received their last dose of antiviral medication (if applicable) and has been off it for at least 48 hours.
- The patient has been asymptomatic for 72 hours.
- The patient has been afebrile for at least 72 hours.
• At least 10 days have passed since symptoms first appeared.
• At least 72 h have passed since recovery (resolution of fever without the use of fever-reducing medications and improvement in respiratory symptoms).

In asymptomatic patients, duration of 10 days after the day of exposure is considered.

If a test-based strategy is used, patients may discontinue infection control precautions when:

• There is resolution of symptoms (absence of fever without the use of fever-reducing medications and improvement in respiratory symptoms)
• There are two negative results of a molecular assay for COVID-19 from respiratory specimens collected ≥24 h apart

For asymptomatic individuals, infection control precautions can be discontinued after obtaining two negative results of a molecular assay for COVID-19.

In immunocompromised patients, a test-based strategy may be preferred as the duration of infectiousness may be prolonged and difficult to ascertain, or if time-based strategy is used, then it may be reasonable to continue precautions for up to 20 days [31].

Some studies have suggested the use of cycle threshold (Ct) to help guide decisions regarding infectivity. Higher Ct values indicate fever RNA copies and a cutoff of 24 can differentiate infective activity [35, 36]. However, as these assays have not been standardized, the results can vary, and as current situation, it cannot be recommended for discontinuation of precautions. Similarly, studies have been investigating the correlation between the development of antibody and disease activity, but data are insufficient to promote the use of antibodies to guide decisions.

14.2.12 Conclusion

Prevention of spread of COVID-19 is a major challenge. Countries worldwide are engaged in developing vaccines, and they remain the principal strategy in the fight against the disease. However the implementation of vaccines is a tardy process that requires rigorous evaluations and trials to determine efficacy as well as safety before they are accepted. Though COVID-19 seems to be less fatal than prior outbreaks caused by the family of coronaviruses, the higher contagiousness has led to far more deaths and a massive burden on health-care resources. Very few management strategies have found success, and so the main strategy against COVID-19 currently remains prevention of transmission. Controlled trials (considered one of the highest levels of evidence) about methods of prevention may be difficult and even unethical; thus much about the disease transmission and prevention has remained poorly understood.
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