

Dynamics of Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 and Its Control Measures

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Abstract

Coronavirus disease 2019 (COVID-19) caused by the β coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a zoonotic disease that has spread beyond the site of outbreak in Wuhan, China, to become a pandemic of magnanimous proportions. As the whole world is reeling under the burden of its morbidity and mortality, researchers are busy tracing its origin, deciphering its transmission dynamics, devising new, rapid, inexpensive, accurate diagnostic modalities, testing potent vaccines, and exploring effective therapeutic measures. Although till date much is unknown about the novel virus, the present review attempts to provide an insight to the transmission dynamics of SARS CoV2 and cover the various control measures that has been adopted to control its transmission.

Keywords: control measures, coronavirus disease 2019, severe acute respiratory syndrome corona virus 2, transmission dynamics

INTRODUCTION

Coronaviruses (CoVs) represent a large family of viruses, some of which have previously caused severe human diseases such as severe acute respiratory syndrome (SARS) in 2002–2003 and Middle East respiratory syndrome (MERS) in 2012. However, the outbreaks were mostly limited to their place of origin and not as widespread as the present one caused by the novel Coronavirus which has been termed as SARS corona virus 2 (SARS-CoV-2) by the International Committee of Taxonomy of Viruses.^[1]

The series of events started from December 31, 2019, when the World Health Organization (WHO) China Country Office was informed of cases of pneumonia of unknown cause detected in the city of Wuhan, Hubei Province, China. A link was traced to a wholesale fish and live animal market in Wuhan and according to media reports, the concerned market was closed on January 1, 2020 for environmental sanitation and disinfection.^[2]

Chinese authorities made a preliminary determination that they were caused by a novel (or new) coronavirus, by ruling out the possibilities of other common respiratory pathogens. Their scientists rapidly isolated the novel coronavirus virus on January 7, 2020, and came out with its genome sequencing.^[3]

Due to the capacity and experience of the robust Chinese public health system to tackle such outbreaks and the paucity of detailed information about the source, epidemiology and transmission dynamics about the new virus, WHO did not, at that time, recommend any specific measures for travelers and advised against any travel or trade restrictions on China based on the current information available on that event.^[3] However, the travelers with respiratory illnesses were encouraged to seek medical attention and share their travel history to the concerned place with their health-care provider.^[3]

The pathogen was named as 2019-novel coronavirus on January 12, 2020, by the WHO^[4] In January 30, with cases in and outside of China, the WHO raised the alert and declared the disease as a public health emergency of international concern^[5] under International Health Regulations (2005). On February 11, 2020, the WHO officially named the disease as

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coronavirus disease 2019 (COVID-19) and Coronavirus Study Group of the International Committee proposed to name the new coronavirus as SARS-CoV-2.^[6] Subsequently, as the cases continued to rise throughout the world, the disease was officially declared as pandemic on March 11, 2020, by WHO.^[7]

THE TRANSMISSION DYNAMICS

The tremendous increase of cases throughout the world led to extensive study and research of novel virus and how it is transmitted. Understanding the dynamics of transmission is the fundamental of any infectious disease modeling. Progression of infection from one person to another with lots of asymptomatic/symptomatic carrier in the process finally decides infectiousness and is dependent on pathogenicity and virulence of the organism. In COVID-19, the agent SARS-CoV 2, the host human and the environment seem very conducive for the epidemiological triad to thrive and breaking any one of its arm remains the preventive mainstay.

The epidemic could be traced back to Wuhan, China, since December 12, 2019, and was possibly related to a seafood market though there is not much evidence to prove that.^[6] Bats are known to harbor a myriad of coronavirus (including SARS-CoV-like and MERS CoV-like viruses) and the genome of SARS-CoV2 showed 96.2% overall genome sequence identity with the Bat CoV RaTG13.^[8] This makes bats a suspect for a potential natural reservoir for SARS-CoV2 which may spread to humans through some unknown intermediate hosts as bats are not sold in sea food market in Wuhan.^[6,9]

Although the source and transmission route of the outbreak remains elusive much research has gone into the transmission dynamics of the novel virus. SARS-CoV-2 is a single-stranded RNA virus, with RNA genome size of approximately 30,000 bases and viral particle size comprised between 70 and 90 nm.^[10] It has got a spike glycoprotein (S) on the envelope which gives it a crown-like appearance when viewed an electron microscope and hence it got its name as “Corona” literally means the crown.

Wan *et al.*^[11] inferred that the since receptor binding domain including the receptor binding motif of SARS Co-V2 is similar to that of SAR CoV, it uses the same angiotensin-converting enzyme 2 receptors for binding. In addition, this novel virus has got certain critical structural residues rendering it capable of human infection and capacity for human-to-human transmission.^[11]

As the more and more cases were reported the transmission dynamics of human-to-human transmission has become much clearer.

According to the current evidence, the major transmission routes are by respiratory droplets and contact routes.^[12]

Respiratory droplets are generally considered to be of size >5–10 µm in diameter and they are primarily responsible for disease transmission. These are generated by coughing

and/or sneezing of symptomatic patients, which then reach the mucous membrane of the nose, mouth, or eye of another person or are inhaled. According to Xie *et al.* droplet propagation depends upon many factors, including the particle size, the speed of exhaled air as well as the temperature and humidity of the environment.^[13] They showed that the large respiratory droplets usually fall within an approximate distance of 1 m (approximately 3 feet) during normal breathing process (exhaled air velocity of 1 m/s) while coughing (velocity of 10 m/s) or sneezing (velocity of 50 m/s) will enhance the propagation distance to 2 m and 6 m, respectively.

Airborne transmission refers to the presence of microbes within droplet nuclei, which are particles <5 µm in diameter, and which result from the evaporation of larger droplets or exist within dust particles.^[11] The major problem is that, these infected droplet nuclei may remain suspended in the air for long periods of time and may be transmitted to others over distances >1 m.

In respect to COVID-19, the WHO had been guarded and has opined that airborne transmission in specific circumstances and during aerosol generating procedures such as endotracheal intubation, bronchoscopy, open suctioning, administration of nebulized treatment, manual ventilation before intubation, turning the patient to the prone position, disconnecting the patient from the ventilator, noninvasive positive-pressure ventilation, tracheostomy, and cardiopulmonary resuscitation.^[12] However, in their subsequent scientific brief on July 9, 2020, WHO indicated that the work presently going on to prove the possibility of airborne transmission in absence of aerosol generating procedures particularly in poorly ventilated crowded indoor settings.^[14] However, the amount of aerosol generated or exhaled during breathing, talking, coughing or sneezing has not been quantified and the infectious dose of SARS-CoV2 that can spread through the aerosols has also remained elusive.

The size of droplets generated by cough is highly variable and may contain virus containing particles within the range of aerosols, thus promoting all national and international health-care agencies to suggest at least 2 m (i.e., 6½ feet) social or physical distancing.^[15-17]

Droplet transmission may also occur through fomites in the immediate vicinity of the infected person.^[18] The respiratory droplets from the infected person are too heavy to be airborne and they get deposited on many environmental surfaces or these surfaces may get contaminated by the touch of the infected person. Other persons may then get infected by touching these contaminated objects/surfaces and then touching their nose, mouth, or eyes.^[15]

Other than respiratory secretions including sputum, there has been some studies that show COVID-19 infection may lead to intestinal infection and that the virus can be present in faeces.^[19,20] Wang *et al.* in their study on various clinical samples found the presence of viral RNA as well as live virus

in stool samples.^[20] The presence of live virus indicate that stool might play an important role in disease transmission. Tang *et al.*^[21] detected virus by reverse transcription polymerase chain reaction (PCR) in stool specimens in cases where respiratory tract specimens were negative and had suggested that stool might be considered, in addition to respiratory tract specimens, for routine diagnostic screening. Zhang *et al.*^[22] also expressed concern that SARS CoV 2 may thus spread by the oral-fecal route. However, the WHO maintains that there has not been any case of COVID-19 transmitted by faeco-oral route.^[12] Besides stool, viral RNA has also been detected in blood samples^[20,22] and urine samples.^[23,24]

Few studies like that of Santarpia *et al.*^[17] and Guo *et al.*^[25] have detected viral RNA of the virus in air samples in intensive care units, wards, or rooms having COVID-19 patients while some others have failed to detect so.^[26] More so, WHO states that the detection of RNA in environmental samples based on PCR-based assays is not indicative of viable virus that could be transmissible.^[12]

Transmission by fomites is also an important route of transmission. The persistence of the virus on various surfaces for considerable time poses a great threat to curb its transmission. Under experimental conditions, van Doremalen *et al.* compared the aerosol and surface stability of SARS CoV 1 and 2.^[27] They inferred that just like its predecessor, aerosol, and fomite transmission of SARS-CoV-2 is plausible. They found that SARS-CoV-2 remained viable in aerosols for 3 h with a reduction in infectious titer from $10^{3.5}$ to $10^{2.7}$ TCID₅₀ per liter of air. It was also seen to be viable on average for about 6.8 h on plastic surfaces and about 5.6 h on stainless steel surfaces, and viable virions were detected up to 72 h postexposure. SARS-CoV-2 appeared more stable on plastic and stainless steel than on copper (4 h) and cardboard (24 h), and viable virus was detected up to 72 h after application to these surfaces. An analysis of 22 studies by Kampf *et al.* revealed that human CoVs (HCoV) such as SARS coronavirus, MERS coronavirus or endemic HCoV can persist on metal, glass, or plastic for up to 9 days with the duration of persistence becoming shorter at temperatures $>30^{\circ}\text{C}$.^[28] Thus, the disease can spread both by direct contact (shaking hands or touching the infected person) or indirect contact (touching fomites or inanimate objects contaminated by virus from the infected persons). This is particularly important in household transmission which is very high in COVID-19. In epidemiology, the infectivity of a contagious disease is expressed as basic reproduction number or R_0 (pronounced as R nought). It signifies the number of secondary cases induced by a single-infected individual in a susceptible population. This R_0 depends on several factors including the infectious agent, the population. In an initial publication with early data, WHO estimated an R_0 of 2–2.5.^[29] Read *et al.* determined the R_0 to be of 3.1.^[30] Majumder and Mandl used Incidence Decay and Exponential Adjustment model to estimate R_0 to be between 2.0 and 3.3^[31] while Hao *et al.* estimated it as 3.54.^[32] The highest R_0 has been reported by Tang and his team with a

staggering value of 6.1.^[33] However, as the disease progresses and some people might be immune and/or preventive measures are being undertaken, “ R_c ” or simply “ R ” which signifies the effective reproduction number might be more practical to evaluate. However, as the epidemic progresses the R and other epidemiological parameters like doubling time will change subject to data from different parts of the world.

Another important problem leading to the heightened transmission rate is shedding of virus by patients in their asymptomatic and presymptomatic stages of the disease^[34,35] which means that the patients start shedding virus and infecting others before they are diagnosed based on their symptoms. This makes the control of transmission very difficult in comparison to the outbreak of SARS-Co V 1.

THE CONTROL MEASURES

Risk perceptions determine precautionary behavior especially in infectious diseases. Human behavior is dependent on a multitude of factors and need intense awareness generation, IEC (information, education, and communication) and behavior change communication to bring in sustainable changes. Control measures are usually primary or secondary. Health education and specific prevention belong to primary prevention which has a role especially in pre pandemic areas. However, secondary prevention like screening and early diagnosis holds the key. Screening clinics, identified quarantine centers, well-formulated testing policies and quarantine policies, dedicated COVID team help in screening the suspects and isolating them from the general population. Breaking the chain of transmission is the most crucial step and is attempted by lockdown and strictly enforcing quarantine measures.

A precautionary approach should be taken to control and prevent infections particularly while dealing with a pathogen whose transmission dynamics are yet to be understood in totality. The goal remains to cut down the transmission chain and keep the R to <1 as far as possible and at the same time care for those who are affected. Special attention need to be paid to susceptible population groups such as children, elderly, health-care workers as well as those with co-morbidities.

On February 4, the WHO Director General had briefed the Secretary General of United Nations and requested to activate the crisis management policy.^[36] On February 6, 2020, the UN Development Coordination Office introduced the COVID-19 Strategic Preparedness and Response Plan (SPRP). The SPRP outlines the essential public health measures to support the United Nation Country Teams to prepare for and respond to COVID-19 in a comprehensive and efficient way. Each country was advised to its own COVID-19 Country Preparedness and Response Plan including the “8 pillars” of priority steps and actions which are as follows:

- Country-level coordination, planning, and monitoring
- Risk communication and community engagement
- Surveillance, rapid-response teams, and case investigation
- Points of entry

- National laboratories
- Infection prevention and control
- Case management
- Operations support and logistics.^[36]

However, testing for new cases, tracing for contacts and treatment of the affected remain the mainstay of the control measures. The control strategies can be divided at the international and national level, at the facility level, and at the individual level.

The international and national level strategies include sharing of logistics, research, and resources along with monitoring and surveillance. The national strategies also include setting up and improving on the infrastructure for virus research and diagnostic laboratories, health care facilities dedicated for treating COVID patients as well as strengthening the public health network. Information, education, and awareness generation among health-care workers and general population coupled with formulation of standard operating protocols for screening, diagnosing and treating, form a major part of control strategies. Some of the other control and preventive measures are:

1. Awareness generation among common people regarding the routes of transmission and necessary precautionary steps
2. Imposing travel restrictions to and from affected areas or countries
3. Detection and treatment of affected persons
4. Contact tracing followed by isolation of exposed symptomatic cases and quarantine of exposed asymptomatic patients
5. Categorization of areas into special containment zones with restriction of movement as per number of positive cases
6. Avoidance of social or mass gatherings
7. Use of face covers, masks, and other personal protective equipment as per the risk
8. Ensuring Hand hygiene: Frequent hand washing in five essential steps should be done to cleanse all the areas of the hand, with either soap and running water for 40–60 s, or alcohol-based hand sanitizer (with alcohol content > 65%) for 20–30 s. This should be done particularly after using the toilet, coughing or sneezing, before preparing food or eating, after touching surfaces such as door handles and before touching the face. Soap and water should always be used if the hands are visibly soiled
9. Ensuring cough hygiene: A cough etiquette should be strictly maintained. While coughing or sneezing a single use tissue paper or the crook of the elbow should be used and never into the hands. The tissue should immediately be discarded safely and hand hygiene performed
10. Avoidance of repeated face touching
11. Physical distancing: It refers to the measures to minimize direct contact with other people in public places. This includes avoidance of greeting by handshake or any physical contact and maintaining of safe (at least 1 m and preferably 2 m) distance from the nearest person
12. Avoidance of going out if feeling sick and avoiding contact with sick people
13. Avoidance of spitting in public places
14. Active monitoring and surveillance
15. Maintenance of household hygiene and sanitization.

A health behavior model which is a widely used tool can be used to predict the precautionary behavior of a population and is often considered an index for the assessment of control behavior in a population.

CONCLUSION

Since there is no curative treatment or vaccine that can prevent the disease, the precautionary and various control measures remain the mainstay of curbing the transmission chain and flattening the curve. While the scientists and researchers throughout the world are working relentlessly for devising rapid, accurate, less expensive diagnostic methods, effective treatment, and potent vaccines, cooperation of the general population is of paramount importance in controlling the pandemic which has literally changed the way we used to live.

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Conflicts of interest

There are no conflicts of interest.

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