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Review Article

SARS-CoV-2 (COVID-19) Transmission, Preventive Measures and Disinfection Strategies

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Abstract

China reported incidence of sever pneumoniae cases with unknown etiology to World Health Organization (WHO) in late December 2019, later the cause of the disease was identified as the novel beta-coronavirus, SARS-CoV-2. Within 3-4 months of duration, most countries of the world have started reporting cases of this novel virus and WHO declared it a pandemic. Mode of disease transmission for this virus is via respiratory droplets and contact with aerosol infected surfaces. Here we reviewed the direct and indirect mode of transmission of disease, stability of virus on different surfaces and effective disinfection methods to curb the transmission of the same. This information can be helpful in defining disinfection strategies and policies of preventive measures.

Keywords: SARS-CoV-2; Covid-19; Preventive Measures; Disinfection; Transmission; Hand Hygiene

Introduction

The whole world is fighting against biggest pandemic of the century. Corona virus disease 2019 (COVID-19) caused by severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) emerged from Wuhan, China in late 2019 and is now causing pandemic. Despite of lockdown imposed in many countries of the world for few months, social distancing and proper sanitization protocol and preventive measures in place, world has witnessed continues continuous increase in the number of Covid-19 cases. As of December 12th 2020, 6,86,30,771 confirmed cases of COVID-19, including 15,64,445 deaths have been reported by WHO. This includes more than 15 lac United States population, 9.7 lac of Indian population followed by other countries. During the lockdown period only essential services were allowed than also the cases have been increased considerably. The index case of the disease, caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) was identified in six months ago. Since then, government authorities have taken aggressive measures to blunt the exponential spread of this coronavirus. Social distancing has been used as important tool to further prevent the spread of COVID-19.

While preventative measures have been imposed globally, few select nations have registered noticeable propagation of COVID-19. As per the epidemiologic data from WHO, some countries have exponential increases in disease incidence, while others seem to have "flattened the curve." Despite of having social distancing, increased number of COVID-19 cases put a question mark on our complete scientific understanding of disease transmission modes. If we have knowledge about mode of transmission, we can curb the spread of this disease. Virus transmission can occur by direct contact with infected people and indirect contact with surfaces in the immediate environment or with objects used on the infected person. Till now we have only focused on social distancing which means keeping distance from other individuals but its effective when mode of transmission is only by direct means i.e. through individuals. In this article, other indirect mode of transmission of corona virus through non-living things and surfaces has also been reviewed along with direct mode of transmission.

We discuss the ability of this novel corona virus to remain viable on environmental surfaces from hours to days and describe its increased virulence characteristics. Furthermore, we will also discuss about how to take preventive measures to curb the spread of corona virus.

Mode of transmission of corona virus

Direct mode of transmission

Direct mode of disease transmission involves the transmission of the virus through physical contact between an infected host or a carrier and a susceptible individual. Direct transmission is a potent route since the viral load can be large, and the virus spends a shorter amount of time outside of a host compared with other routes of transmission.

Through droplets

Normally human droplets are generated from infected person primarily duringbreathing, talking, sneezing, coughing which includes epithelial cells and cells of the immune system, various infectious agents (e.g. bacteria, fungi and viruses) along with physiological electrolytes contained in mucous and saliva. Transmission occurs when these droplets, containing microorganisms, are propelled a short distance. These droplets vary in size from 1 µm to 60 µm. Upper respiratory tract which includes oropharynx — nose and throat areas generates traps droplets of >5 µm size, whereas droplets ≤5 µm have the potential to be inhaled into the lower respiratory tract (the bronchi and alveoli in the lungs). Sneezing can produce as many as 40 000 droplets between 0.5–12 µm in diameter [1,2] which may be expelled at speeds up to 100 m/s [1]. Talking for five minutes or coughing may produce 3000 droplet nuclei [1,2]. In normal conditions, droplets smaller than 100 µm in diameter would completely dry out before falling approximately 2 m to the ground. However, the degree to which SARS-CoV-2 can be transmitted by aerosol remains unclear but a study in Wuhan hospitals reported that the virus was detected in aerosol samples from areas open to the general public, $\sim 10^1 - 10^2$ m from the source [3].

A study on SARS-CoV-2 infected patients in isolation rooms concluded that contamination of high-contact surfaces such as doorknobs and bed-rails, as well as air outlet fans which indicated virus transfer from aerosols to a surface [4]. This is reason behind currently used social distancing norms of keeping at least 2 m distance among the individuals.

Preventive measures against viral transmission

For reducing exponential rise in incidence rates of disease transmission, social distancing has been applied aggressively by the governing authorities globally. These preventive measures are part of public health policies formed after 1918 influenza pandemic. Few U.S. cities observed considerably lees mortality by following distancing to address the spread of the disease during 1918 pandemic. Diseases spread by transmission of pathogens which can be spread from person to person within a 1-2 m (6-8 feet) (Figure 1) distance via respiratory droplets can be effectively stop spreading by social distancing which is proven practice in past [5,6]. Success of social distancing depends upon the community behavior as it can stop the transmission of disease from carriers, infected person to healthy persons. It prevents opportunities for potential viral exposures among the communities. This ultimately helps in reducing number of critical illness which needs medical treatment and in turn help flattening the disease incidence curve. This helps the governing systems to strengthen health care system that takes care of critical patients and who eventually need ventilators in COVID-19 disease. It also gives time and chance to critically ill patients to survive by obtaining life-saving supportive therapy in hospitals which in turn reduces mortality rate. Absence of social distancing practice may lead to sharp increase in the number of critically ill patient and lack of life support medical attentions can worsen the situation.

In current scenario, mode of transmission of SARS-CoV-2 is person to person through respiratory droplets (CDC, 2019, WHO 2020). As per the recommendation by Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO), following preventative measures are considered to suppress the spread by droplets: (1) avoid touching viral entry points, such as eyes, nose, and mouth, (2) cover the mouth when coughing or sneezing, (3) wear a face-mask (4) wash hands with soap and (5) practice social distancing by putting at least 6 feet of distance between individuals.

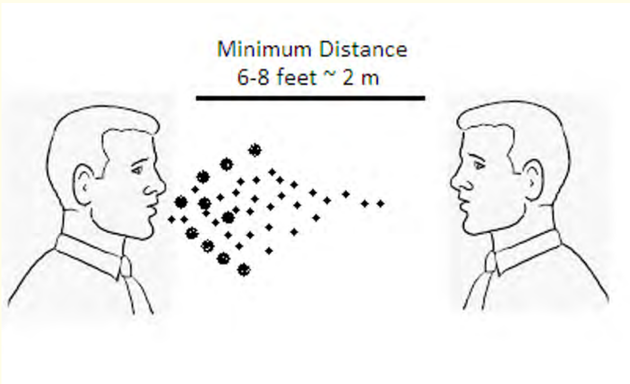

Figure 1: Schematic representation of distance travelled by SARS-CoV-2 virus via droplet transmission.

Preventive measures against direct mode of transmission

Masks

Masks are very crucial for any individual to stay protected against direct viral transmission through droplets or aerosols. The average size of the corona virus-shaped spherical particles is estimated to be about 0.125 microns (125 nm) using an electron microscope. But size of them varies from 0.06 microns to 0.14 microns (Zhu 2020). Respiratory infections can be transmitted through different sized droplets. The droplet particles of >5-10 microns in diameter are called respiratory droplets whereas <5μm in diameter are referred to as droplet nuclei. As per the studies reported, COVID-19 virus is primarily transmitted through respiratory droplets and contact route. Commonly used masks, by health care workers and the general public, capture particles with a diameter of >0.3 microns. Ability of capturing capacity of mask depends upon the filter used in it. Following are masks available and their capacity of capturing particles >0.3 microns size: N100 respirator - 99.97%, FFP1 respirator- 99.95%, N95 respirator- 95%, FFP2 respirator - 94%, FFP1 respirator- 80%, Surgical mask- 80% [7].

Apart from masks, handkerchief, cotton cloths and homemade masks are also available in the market. As per our knowledge, no any study has claimed efficacy of them against transmission of SARS-CoV-2. However, all of these will help in protecting spread of infection as these will work as barrier between hands and mouth, nose.

Lockdown and social distancing

Above these, government-mandated social distancing measures such as "lockdowns" and "stay at home" orders are also effective ways to minimize the spread of SARS-CoV-2 through droplet transmission. Fact is that, despite all aggressive preventive measures, COVID-19 pandemic has spread to almost every nation in the world. Best example of this was Diamond Princess Cruise ship which was carrying 3,711 passengers and crew members. After 14-day voyage, 10 cases tested positive for COVID-19 on February 4, 2020. As a response, ship was quarantined for 14 days with all social distancing principles practicing on board. But after quarantine period, total of 634 cases reportedly tested positive for COVID-19 which means that this was not the best practice implemented to contain COVID-19. The reason behind this situation was widespread transmission of fomites or COVID-19 aerosols by interconnected central ventilation systems between ship cabins. This is the case with all the countries which have imposed lockdown for around two months but have found exponential increase in number of COVID-19 cases.

Indirect mode of transmission

Through miscellaneous personal items

A study conducted by at University of Nebraska Medical Center (UNMC) to investigate the mode of viral transmission. Researchers have collected various samples from containment and quarantine units' study after 10 and 18 days of stay of COVID-19 positive patient. They examined virus presence through PCR test on personal items handled routinely by individuals in isolation like cellular phones, exercise equipment, television remotes, and medical equipment, room surfaces like ventilation grates, tabletops, and window ledges and toilet samples. Of these, 76.5% of all personal items were found positive for SARS-CoV-2 [8]. This proves the virus could transmit by touching an object or surface with virus present from an infected person, and then touching the mouth, nose or eyes.

Environmental surfaces

Despite having strict lockdown with preventive measures like social distancing, exponential growth has been observed in all the countries. Most countries allowed essential services and purchase of the same like milk, medicine and routine groceries. Social distancing can prevent the transmission of corona virus by some extent but environmental surfaces can still do the same depending upon viral affinity towards the surface. Contaminated objects or surfaces, referred to as fomites play important role in transmission of viruses. Virus adsorption and viability is also affected by environmental variables such as temperature, humidity, and resident micro fauna. Normally, high temperature and moderate humidity levels have adverse effects on the persistence and viability of corona viruses and true for other viruses as well (Kim., *et al*. 2018). Researchers have tried studying the stability of SARS-CoV-2 virus on various surfaces under different environmental conditions. In a study (Chin A, 2020), 5 µL droplet of virus culture (~7·8 log unit of TCID50 per mL) was pipette on a surface and left at 22°C with a relative humidity of around 65%. The inoculated objects retrieved at desired time-points were immediately soaked with 200 µL of virus transport medium for 30 minutes to elute the virus which may not reflect actual transmission potential to pick up the virus by casual contact. As per this study, virus was found inactive after 3 hour incubation on printing and tissue paper, and after 24 hours on treated wood and cloths. Virus was found to be active for longer duration on smooth surfaces like glass and Banknote, stainless steel and plastic etc. Authors have also found presence of detectable level of infectious virus on the outer layer of a surgical mask on day 7. Refer the list of surfaces and duration of active virus on them in the table 1 [9].

Study Parameters	Surface Type	Survival time
Study was conducted at 22°C temperature and 65% relative humidity.	Cloth	2 days (48 hours)
	Steel	7 Days (168 hours)
	Glass	4 Days (96 hours)
	Plastic	7 Days (168 hours)
	Wood	2 days (48 hours)
	Bank note	4 Days (96 hours)
	Paper	3 Hours
	Tissue Paper	3 Hours
	Surgical mask (Inner Layer)	7 Days (168 hours)
	Surgical mask (Outer Layer)	7 Days (168 hours)

Table 1: Survival time of SARS-CoV-2 virus on various surfaces.

Another study have analyzed decay of SARS-CoV-2 and SARS-CoV-1 in aerosols and on various surfaces like plastic, stainless steel, copper, and cardboard by using a Bayesian regression model. They generated aerosols (<5 µm) containing SARS-CoV-2 (105.25 50% tissue-culture infectious dose [TCID50] per milliliter) or SARS-CoV-1 (106.75-7.00 TCID50 per milliliter) using three-jet Collison nebulizer and fed into a Goldberg drum to create an aerosolized environment. Resulted aerosols were comparable with actual patient samples from the upper and lower respiratory tract. They observed SARS-CoV-2 was more stable on plastic and stainless steel than on copper and cardboard. They found viable viruses for up to 72 hours on plastic surface, 48 hours on stainless steel surface, 4 hours on copper and 24 hours on cardboard surface.

Based on the finding of the aforementioned studies, it is evident that SARS-CoV-2 virus can remain active for longer duration on different surfaces. Talking, coughing, breathing and sneezing generate aerosols and droplets which can travel through air. Distance travelled by droplet depends upon the velocity, size of droplets and ventilation. Surfaces which are in frequent contact with individuals pose higher risk of contamination. A study conducted for a hospital setting showed contamination on many high-contact surfaces like door handles, bed rails, tables, call/control panels, other near-patient surfaces, office equipment and sterile packaging [10,11]. Another study of the isolation rooms of SARS-CoV-2 infected patients in Singapore found similar results [4]. However, viral transmission by footwear was found to be low in a study where the floor of the isolation room and the shoes worn by individuals entering and exiting the room tested positive for SARS-CoV-2 but the floor immediately outside tested negative. One case study conducted to study the SARS-CoV-2 transmission in a restaurant in China has concluded that droplets were transmitted through air-conditioned ventilation [12]. Asymptomatic carries can easily carry and transmit the COVID-19 infection in public places or shops by direct (droplet) or indirect (through environmental surfaces) mode of transmission, which can be probably one of the reasons behind increased COVID-19 cases despite lockdown and social distancing.

Various methods of viral dis-infection

During infection process, virus fuses with a host cell, insert its genome into the cell, and then replicate within the host [13]. For completing infection process, an enveloped virus must have an intact envelope and nucleocapsid. For effective functioning of disinfecting agent and inactivate virus, at least one of these components needs to be disrupted [14]. Complete understanding of virus persistence on different surfaces in various environmental factors can help in decision making for disinfection protocols. The ability of a virus to remain live and transfer between different surfaces is an important factor in the overall infectivity of a virus by means of fomite transmission.

- **Temperature effect:** Sars-CoV-2 virus was found viable for more than 14 days at 4°C and >7days at 22°C temperature. This indicates that in European countries and United States where average temperature during the spread of pandemic was below 22°C virus spread through fomite transmission may be higher. Same study also found viral titer undetected at 37°C for 2days, 56°C for 30 minutes and 70°C for 5 minutes [15]. These findings eliminated the speculation of decreased virus transmission during summers in India, as in maximum Indian cities report temperature around 45°C-47°C.
- **Ph effect:** Ph has no effect on Sars-CoV-2 virus and it can survive in range of Ph from 3 to 10 [15].
- **Radiation:** Studies reported that UVGI methods can be used effectively to eliminate viruses in health-care facilities, schools, indoors, etc—by using special ultraviolet radiation systems (ultraviolet C lamps, chambers) [16]. More than 15 min of UV-C treatment can inactivated the virus while UV-A light had no effect on viability, regardless of duration of exposure [17]. Gamma radiation found to be ineffective in inactivating SARS-CoV virus even at high dose up to 2 × 10^6rad [18]. Sunlight also contains UV wavelengths but sunlight that reach the surface of the earth is between 290 and 400 nm, as UVC is completely absorbed by the ozone layer, so sunlight cannot kill the virus [19].
- **Chemical Disinfectants:** There are lots of chemical disinfectants currently available to combat the spread of SARSCoV-2. Effectiveness of disinfectant varies upon the virus inactivation mechanism. Disinfectants function by three ways of inactivation 1)by disrupting the lipid layer of the envelope (e.g., ethanol and detergents) 2) by modifying protein sites of capsid (e.g., chlorine and glutaraldehyde) and 3) degradation of the nucleic viral nucleic acids by reacting with the viral nucleotides and amino acids (e.g., chlorine) [20].

In case of SARS-CoV-2, reduction of viral load from ~7.8 log10 TCID50/mL to undetectable levels was reported with disinfection treatment of 1% and 2% household bleach, 70% ethanol, 7.5% povidoneiodine, 0.05% chloroxylenol, 0.05% chlorhexidine, and 0.1% benzalkonium chloride at room temperature within 5 minutes in suspension tests. Where as for other corona viruses like SARS-CoV-1, MERS-CoV, and MHV, ethanol of 78%, 80%, 85% and 95%; 2-propanol of 75%;a mixture of 45% 2-propanol and 30% 1-propanol; 0.21% sodium hypochlorite; and 1%, 4% and 7.5% povidone iodine were found to reduce viral activity by at least 4 log10 within 30 seconds in suspension tests. This information is available in summarized form in table 2.

Disinfectant	Time required for elimination
Household bleach (1:49)	5 minutes
Household bleach (1:99)	5 minutes
Hand Soap Solution (1:49)	15 minutes
Ethanol (70%)	5 minutes
Povidone-iodine (7.5%)	5 minutes
Chloroxylenol (0.05%)	5 minutes
Chlorhexidine (0.05%)	5 minutes
Benzalkonium chloride (0.1%)	5 minutes
2-Propanol (75%)	5 minutes

Table 2: Disinfectant concentration and time required for elimination of SARS-CoV-2.

Heat treatment

Heat treatment is a well practiced method for disinfecting surfaces. Viral capsid proteins are denatured and RNA is damaged at temperatures more than 80°C [14]. A study has reported inactivation of SARS-CoV-2 within 5 minutes at 70°C, with a reduction from an initial concentration of ~6.8 log10 TCID50/mL to undetectable levels [15]. Most common sterilizing technique used in a laboratory or clinical environment. Autoclaves works by producing steam at high temperatures (~132°C) in a pressurized chamber which can kill most microbes, including viruses. Most materials can be surface sterilized by exposing to high temperature and pressure environment for varying amount of time based on the material and size of the object. Glass and plastic surfaces can be sterilized in ~30 minutes where liquids can take 30-60 minutes. In one study, cotton swabs containing avian coronavirus and avian pneumovirus were inactivated after heat treatment using an autoclave for 20 minutes and in a microwave oven for 5 seconds [21].

Hand hygiene

According a study published, adults touch their faces 23 times per hour which increases the risk of infection, this risk can be reduced by frequent hand washing [22]. However, effectiveness of hand washing depends upon the frequency, the antiseptic used, and thoroughness [23]. Few studies investigated effectiveness of hand washing on reducing infectivity by varying hand washing duration at 15 and 20 seconds [24-26]. As per the guidelines of CDC also, hand washing is recommended for a minimum of 20 seconds (CDC 2020). These studies, uses finger pad method, where pre-cleaned finger pad is infected with virus followed by subject to exposure to an antiseptic by static contact with the finger pad [27,28]. As per ASTM guidelines, virus titer should be reducing by 4 log10 (99.99%) to consider antiseptic effective for hand washing (ASTM 2017). For health care workers of hospitals, WHO recommends 5 critical points to wash hands which are: 1) before contacting patient, 2) before a cleaning procedure, 3) after exposure to bodily fluids, 4) after contact with a patient, and 5) after contact with fomites surrounding patients (WHO 2009).

Effectiveness of different antiseptics varies depending on their content and the structure and survival ability of viruses against which they are used. Alcohol and isopropanol-based antiseptics (60-80% ethanol) are the found most effective and non-hazardous antiseptic for enveloped viruses like SARS-CoV-2 (WHO 2009). Some of the WHO-recommended antiviral antiseptics are iodophors (0.5-10%), chlorhexidine (0.5-4%), and chloroxylenol (0.5-4%), however all of these are less effective than alcohol (WHO 2009). In a study conducted on SARS-CoV-1 reported reduction of >4 log10 in 30 seconds using ethanol and isopropanol formulations at 80% and 75% concentrations, respectively [29].

Concluding Remarks

SARS-CoV-2 infection is spreading at exponential speed in almost all the countries across the world except few which have somehow flattened the curve or stop the infection by strictly following lockdown and social distancing rules. Till date few medicines showed positive impact against Covid-19 but none of them have shown complete effectiveness. There are more than 200 institutes/companies are working on preparing vaccine against SARS-CoV-2 but it will take minimum six months to one year of time to practically available for use. After following more than 50-60 days of lockdown, many of the countries have lifted the lockdown to bring the economy on track with social distancing personal preventive guidelines. Gradually, this will allow all the shops, markets, worship places and commercial factories, organization etc. which will gather more people. In this situation, asymptomatic carriers will also be available who can spread the infection and most importantly by means of fomite transmission. Considering this scenario, knowledge about survival of virus on different surfaces, hand hygiene, effectiveness of ways of eliminating viruses, efficacy of chemicals used as disinfectants etc. will be very important and helpful in curbing the viral transmission. For curbing viral transmission through fomites, effective surface cleaning is very important. For disinfecting floors at offices, houses and schools etc. from SARS-CoV-2, 1-2% of household bleach can be used. For cleaning workbenches, computers, keyboards etc. 70-80% Isopropyl alcohol can be used. All the door handles and knobs, groceries (packed in plastic material) etc. can be sterilized using 70-80% Isopropyl alcohol. All the vegetables must be washed with running water and kept for at least 24 hours in separate space (through studies are not available for the same). Washing hands with soap for 20 seconds or with hand sanitizers (with minimum 70% ethanol/IPA) and wearing mask (preferably N-95 or any three layer mask) is must while going out of home. Developing habits of practicing preventive measures will help us fight against COVID-19 and other diseases which spread through pathogen transmission.

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Conflict of Interest

Authors declare no conflict of interest.

Declaration

Not Applicable.

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