REVIEW ARTICLE

Surface Persistence of SARS-CoV-1 MERS and SARS-CoV-2 Viruses and Effective Biocidal Agents: An Insight

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Abstract

The novel coronavirus disease is the ongoing pandemic that is caused by severe acute respiratory syndrome coronavirus or SARS-CoV-2. The disease continues to create havoc globally and has created fears in the mind of individuals regarding its spread and transmission. Transmission among humans occur through close contact with an infected individual who may produce respiratory droplets while coughing and sneezing which can remain in air and/or settle on inanimate objects. Therefore, knowledge about the persistence of the virus on various surfaces helps in alleviating irrational fears and also aids in controlling the spread of infection. In this review, an effort was made to compile the data on the persistence of the human coronaviruses such as SARS-CoV-1, Middle East respiratory syndrome (MERS), and SARS-Cov-2 on various surfaces and the biocidal agents that are effective against them.

Keywords: Biocidal, Coronavirus, Disinfection, Persistence surface, Survival skin, Survival surface.

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Introduction

On March 11, 2020, the World Health Organization (WHO) declared (SARS-CoV-2 as a pandemic that causes novel coronavirus disease–2019 (COVID-19).

Infected individuals reported with common clinical symptoms involving fever, nonproductive cough, myalgia, shortness of breath, and normal or reduced leukocyte counts.[1] In addition, severe cases of infection presented with pneumonia, SARS, kidney failure, and eventually leading to death.

Transmission among humans occurs via close contact with an infected individual that produces respiratory droplets while coughing or sneezing within a range of 6 ft.[2] Transmission of coronaviruses from contaminated dry surfaces has been postulated including self-inoculation of mucous membranes of the nose, eyes, or mouth. Therefore, it is important to have a detailed understanding of persistence of this virus on inanimate surfaces.[3]

Various types of biocidal agents such as hydrogen peroxide, alcohols, and sodium hypochlorite are used worldwide for disinfection, mainly in healthcare settings.[3]

Dental professionals are at high risk and can become potential carriers of the disease. These risks can be attributed to the unique nature of dental interventions, which include aerosol generation, handling of sharps, and proximity to the patient's oropharyngeal region. If adequate precautions are not taken, the dental office can potentially expose patients to cross-contamination.[4]

The emergence of the COVID-19 and its pandemic nature has exacerbated fears worldwide. With the high levels of fear, individuals may not think clearly and rationally when reacting to COVID-19.[5] Currently, easy access to communication technologies and the spread of inaccurate or false information can increase harmful social reactions, such as fear, anger, and aggressive behavior. Thus accurate information and evidence-based data play a crucial role in managing the current situation.

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A Medline search was conducted in August 2020. The following terms were used along with coronavirus, SARS, MERS, persistence, surface, persistence skin, persistence hands, survival skin, inanimate survival, and disinfection. Publications with human coronaviruses were included. Only one article was found on SARS-CoV-2 that evaluated the stability of the virus in aerosols and common inanimate surfaces.

Therefore, an attempt has been made in this article to compile information on the stability of SARS-CoV-2 and various other human coronaviruses on inanimate objects which are a part of the dental office as well as our routine life and also commonly used biocidal agents that are effective against coronaviruses for surface disinfection.

Stability of Human Coronaviruses on Surfaces

Various studies related to the stability of human coronaviruses including SARS-CoV-2 are presented in Table 1. The surfaces that were studied included copper, stainless steel, aluminum, metal, plastic, cardboard, teflon, polytetrafluoroethylene (PTFE), ceramic, glass, polyvinyl chloride (PVC), silicone rubber, wood, paper, and cloth. Cotton gauzes, latex surgical gloves, disposable gown, and cotton gowns were also evaluated. Table 2 lists out the surfaces

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Table 1: Studies done to evaluate persistence of the coronaviruses on inanimate and living surfaces

Author and year	*Virus and strain used*	*Methodology*	*Method for viral identification*	*Results and conclusion*
Von Doremalen et al.[6]	*SARS-CoV-2* nCoV-WA1-2020 SARS-CoV-1 Tor2 (AY 274,119.3)	Viruses were applied to copper, cardboard, stainless steel, and plastic maintained at 21 to 23°C and 40% relative humidity over 7 days. Aerosols were generated using a three-jet collision nebulizer and fed into a Goldberg drum to create an aerosolized environment. Samples were collected at 0, 30, 60, 120, and 180 minutes post-aerosolization on a gelatin filter	Viable virus in all surface and aerosol samples was quantified by end-point titration on Vero E6 cells.	Aerosol and fomite transmission of *SARS-CoV-2* is plausible, since the virus can remain viable and infectious in aerosols for 3 hours, Copper for 4 hours, Cardboard for 24 hours, Stainless steel for 72 hours (3 days) and plastic for 72 hours (3 days)
Warnes et al.[7]	Human coronavirus 229E	Infected cell lysate preparations of HuCoV-229E were spread over coupons of the test surface and incubated at room temperature. Surface materials used were polytetrafluoroethylene (teflon; PTFE), polyvinyl chloride (PVC), ceramic tiles, glass, silicone rubber, and stainless steel	Virus was removed and assayed for infectivity at various time point by a plaque assay which was a modification of the murine norovirus 1 (MNV-1) assay	Coronavirus persists in an infectious state on common surface materials such as polyfluorotetraethylene (teflon; PTFE), polyvinyl chloride (PVC), ceramic tiles, glass, and stainless steel for at least 5 and 3 days for silicon rubber at 21°C and a relative humidity of 30– 40%
Von Doremalen et al.[8]	MERS-CoV (isolate HCoV-EMC/2012)	Stability of MERS was evaluated under three different environmental conditions on plastic and stainless steel and also aerosols	Collected aerosols were analyzed by quantitative real-time polymerase chain reaction (qRT-PCR) and by virus titration	MERS-CoV virus could still be recovered after 48 hours at the 20°C-40% RH condition, 8 hours at 30°C-80% RH, and 24 hours at 30°C-30% RH. MERS-CoV has the ability to be transmitted via aerosols as well
Chan et al.[12]	SARS-CoV HKU 39849	Virus was placed in individual wells of a 24-well plastic plate (representing a nonporous surface) and dried. The dried virus was then incubated at different temperatures (38, 33, 28℃) at different relative humidity (>95%, 80–89%) for 3, 7, 11, 13, and 24 hours and the residual viral infectivity was titrated. Also virus was incubated at room temperature and relative humidity of about 40–50% for up to 4 weeks	Appearance of cytopathic effects was recorded daily.	The dried virus on smooth surfaces like plastic retained its viability for over 5 days at temperatures of 22–25°C and relative humidity of 40–50%,
Duan et al.[10]	SARS-CoV strain P9	Common household surfaces such as metal, glass, wood board, cloth, and plastic were tested for stability of SARS-coronavirus	For analysis of stability of coronavirus cytopathic effects was observed.	Reduction of infectivity was seen 72–96 hours (3–4 days) after exposure to various surfaces.
Lai et al.[11]	SARS-CoV strain GVU6109	To simulate the event of large droplets that contain SARS-CoV falling on paper and on cotton and disposable gowns, experiments were performed to determine whether SARS-CoV survived on these surfaces.	Each specimen was placed into a Vero E6 cell culture tube and inoculated into cell culture tubes. All of the tubes were incubated at 37°C and were examined after 4 days.	Paper-24 hours Cotton gown- 24 hours Disposable gown- 2 days

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Author and year	*Virus and strain used*	*Methodology*	*Method for viral identification*	*Results and conclusion*
Rabenau et al.[13]	SARS-CoV isolate FFM-1	They studied the stability of SARS-CoV under different conditions, both in suspension and dried on polystyrene surface, in comparison with other human-pathogenic viruses, including human coronavirus HCoV-229E	Residual SARS-CoV infectivity was detected by recognition of cytopathic effect (CPE) on Vero cells and additionally by immunostaining of infected cells using convalescent serum from a SARS patient	In suspension, HCoV-229E gradually lost its infectivity completely while SARS-CoV retained its infectivity for up to 9 days; in the dried state, survival times were 24 hours vs. 6 days.
Sizun et al.[9]	HCoV strains 229E and OC43	Three different surfaces were tested: aluminum, sterile cotton gauze sponges, and sterile latex surgical glove. Aliquots (10 µL) of virus suspensions were dropped on to each surface and allowed to dry.	Infectious virus titers were calculated by the Karber method, using four wells per sample dilution	HCoV-229E infectivity was detectable after 3 hours on various surfaces (aluminum, sterile latex surgical gloves, sterile sponges) but HCoV-OC43 survived 1 hour or less
No data was found to describe the frequency of hands becoming contaminated with coronavirus, or the viral load on hands either, after patient contact or after touching contaminated surfaces.				

MERS, Middle East Respiratory Syndrome; HCoV, human coronavirus; SARS, Severe Acute Respiratory Syndrome; RT, room temperature

and the studies done on them to assess the persistence of human coronaviruses.

Biocidal Agents Effective Against Human Coronaviruses

The various biocidal agents effective against coronaviruses and the studies related to them are listed in Table 3.

Discussion

A novel human coronavirus known as the SARS-CoV-2 emerged from Wuhan, China in December 2019. The disease was declared as a pandemic by the WHO and has spread across the whole world.

Severe acute respiratory syndrome coronavirus being an airborne virus, transmit via the same way as cold and flu virus do. The virus spreads by an infected person on coughing or sneezing leaving small droplets in the air or by stool. So the person who inhales such droplets or touches the infected surfaces may also get infected.[19] Therefore, accurate information regarding the stability of the virus on inanimate objects will help us in preventing and controlling the pandemic.

At the time of data compilation (August 2020) only one article related to SARS-CoV-2 by van Doremalen et al.[6] was available. They evaluated the stability of SARS-CoV-2 and SARS-CoV-1 in aerosols and on various surfaces and estimated their decay rates. Almost all the other studies have presented the stability information of SARS-CoV-1, MERS, or other human coronaviruses.

The reason behind this compilation was to dig out the literature on stability of coronaviruses on various surfaces of routine life, as it has created havoc in the minds of human beings. The undue stress involved due to the spread of this pandemic has caused serious mental health issues leading to high levels of fear and anxiety in individuals. Therefore, this compilation of information aims to lessen that stress.

There are not many studies being conducted on this virus for the best known reason of transmission and spread of infection. However, the study by van Doremalen et al. is a good source of information on the stability of the virus on plastic, stainless steel, cardboard, and copper surfaces.

There is lack of information on specific time duration of stability of other two human coronaviruses (SARS-CoV-1 and MERS) as well. The studies have used commercially available strains mostly, with very few of them using the actual virus due to the threat of infection transmission. However, these studies have made an attempt to provide us with a good source of information. Thanks to the authors!

Other studies included in this article serve as a source of information about the other human coronaviruses. These results cannot be extrapolated directly to SARS-CoV-2 due to the differences between the viruses. Studies have demonstrated that SARS-CoV-2 spike protein has higher affinity to the angiotensin-converting enzyme 2 (ACE2) receptor as compared with SARS-CoV-1 which is 10 to 20 times higher.[20,21] Whereas MERS acts on a different receptor altogether, which is the dipeptidyl peptidase 4 (DPP4) receptor. But similarities have been detected between SARS-Cov-1 and SARS-CoV-2 in terms of genetic sequences. Sequence variation among their genome revealed no significant difference in open reading frames (ORFs) and nonstructural proteins (nsps).[22] Regarding the transmissibility, the reproductive number or Ro of SARS-CoV-2 ranges between 2 and 2.5. Whereas that of SARS-Cov-1 was 1.7 to 1.9 and of MERS was <1. Also higher fatality rates were seen with MERS (34.4%) and SARS-CoV-1 (9.5%) as compared to SARS-CoV-2 (2.3%). Also SARS-Cov-2 generally has a less severe clinical picture, and thus it can spread in the community more easily than MERS and SARS.[23]

Persistence on Various Common Surfaces

Persistence of coronaviruses on steel has been reported to be 72 hours (3 days),[6] 48 hours (2 days)[8] and even 5 days.[7] Persistence of coronaviruses on copper has been reported to be 4 to 8 hours,[6] on aluminum was 2 to 8 hours,[9] and on metals it was found to be 5 days.[10] Persistence of coronaviruses on cardboard was reported to be 8 to 24 hours[6] and on wood it was found to be 4 days.[10] Persistence of coronaviruses on paper has been reported to be between 24 hours[11] and 4 to 5 days.[10] Persistence of coronaviruses on glass was reported to be between 4 and 5 days.[7,10] Persistence of coronaviruses on plastic was reported to be 72 hours (3 days),[6] 8 to 48 hours (< 2 days),[8] 4 days,[10] 5 days,[12] and 2 to 9 days.[13] Persistence of coronaviruses on silicon rubber was reported to be 3 days.[7] Persistence of coronaviruses on teflon, ceramic, and PVC was found to be 5 days.[7] Persistence of coronaviruses on latex

Table 2: Persistence of human coronaviruses on various surfaces

Author	*Viral strain*	*Persistence*	*Reference*
Steel			
Von Doremalen et al.[6]	*SARS-CoV-2* nCoV-WA1-2020 SARS-CoV-1 Tor2 (AY 274,119.3)	72 Hours for both the viruses Viral titer greatly reduced after 48 hours	6
Warnes et al.,[7]	Human coronavirus 229E	5 Days at 21°C at 30–40% RH	7
Von Doremalen et al.[8]	MERS-CoV (isolate HCoV-EMC/2012)	48 hours at 20°C°-40% RH 24 hours (30°C-30% RH 8 hours at 30°C-80% RH	8
Copper			
Von Doremalen et al.[6]	*SARS-CoV-2* nCoV-WA1-2020 SARS-CoV-1 Tor2 (AY 274,119.3)	4 Hours for SARS-Cov-2 8 Hours for SARS-Cov-1	6
Aluminum			
Sizun et al.[9]	HCoV strains 229E and OC43	2–8 Hours at 21°C	9
Metal			
Duan et al.[10]	SARS-CoV strain P9	5 Days at room temperature	10
Cardboard			
Von Doremalen et al.[6]	*SARS-CoV-2* nCoV-WA1-2020 SARS-CoV-1 Tor2 (AY 274119.3)	24 Hours for SARS-Cov-2 8 Hours for SARS-Cov-1	6
Wood			
Duan et al.[10]	SARS-CoV strain P9	4 Days at room temperature	10
Paper			
Lai et al.[11]	SARS-CoV strain GVU6109	24 Hours at room temperature	11
Duan et al.[10]	SARS-CoV strain P9	4–5 Days at room temperature	10
Glass			
Warnes et al.[7]	Human coronavirus 229E	5 Days at 21°C at 30–40% RH	7
Duan et al.[10]	SARS-CoV strain P9	4 Days at room temperature	10
Plastic			
Von Doremalen et al.[6]	*SARS-CoV-2* nCoV-WA1-2020 SARS-CoV-1 Tor2 (AY 274119.3)	72 Hours for both the viruses	6
Von Doremalen et al.[8]	MERS-CoV (isolate HCoV-EMC/2012)	48 Hours at 20°C-40% RH 24 Hours 30°C-30% RH, 8 Hours at 30°C-80% RH	8
Chan et al.[12]	SARS-CoV HKU 39,849	5 Days at 22–25°C-40–50% RH	12
Rabenau et al.[13]	SARS-CoV isolate FFM-1 HCoV-229E	6–9 Days at room temperature 2–6 Days at room temperature	13
Duan et al.[10]	SARS-CoV strain P9	4 Days at room temperature	10
Silicone rubber			
Warnes et al.[7]	Human coronavirus 229E	3 Days at 21°C at 30–40% RH for silicone rubber	7
Latex gloves			
Sizun et al.[9]	HCoV strains 229E and OC43	≤8 Hours at 21°C	9
Disposable gowns			
Lai et al.[11]	SARS-CoV strain GVU6109	2 Days at room temperature	11
Teflon, ceramic, PVC			
Warnes et al.[7]	Human coronavirus 229E	5 Days at 21°C at 30–40% RH for teflon, ceramic, and PVC	7

SARS, Severe Acute Respiratory Syndrome; MERS, Middle East Respiratory Syndrome; HCoV, human coronavirus; RH, relative humidity

Table 3: Various biocidal agents and their concentrations that are effective against human coronaviruses

Author and year	*Viral strain used*	*Concentration*	*Exposure time*	*Reference*
Ethanol				
Siddhartha et al.[14]	MERS-CoV strain EMC	80%	30 Seconds	14
Rabenau et al.[13]	SARS-CoV Isolate FFM-1	95% 85% 80% 78%	30 Seconds	13
2-Propanol				
Siddhartha et al.[14]	SARS-CoV isolate FFM-1 MERS-CoV strain EMC	75%	30 Seconds	14
2-Propanol and 1-propanol				
Rabenau et al.[13]	SARS-CoV isolate FFM-1	45 and 30%	30 Seconds	13
Hydrogen Peroxide				
Omidbakhsh et al.[15]	HCoV strain 229E	0.5%	1 Minute	15
Glutaraldehyde				
Kariwa et al.[16]	SARS-CoV Hanoi strain	2.5%	5 Minutes	16
Rabenau et al.[13]	SARS-CoV isolate FFM-1	0.5%	2 Minutes	13
Povidoneiodine				
Eggers et al.[17]	SARS-CoV isolate FFM-1 MERS-CoV isolate HCoV-EMC/2012	0.23%	15 Seconds	17
Eggers et al.[18]	MERS-CoV isolate HCoV-EMC/2012	7.5% 4% 1%	15 Seconds	18
Kariwa et al.[16]	SARS-CoV Hanoi strain	1% 0.25% 0.23%	1 minute	16

SARS, Severe Acute Respiratory Syndrome; MERS, Middle East Respiratory Syndrome; HCoV, human coronavirus

gloves was found to be <8 hours[9] and on disposable gowns it was reported to be 2 days.[11]

Biocidal Agents Effective Against Human Coronaviruses

The viral load on any inanimate surface cannot be determined especially during an outbreak. So it seems logical to reduce the viral load on these surfaces by disinfection, especially surfaces that are frequently touched. WHO recommends that environmental surface cleaning and disinfection needs to be done consistently and correctly.[24]

Table 3 compiles the biocidal agents that are effective against coronaviruses with their concentration and time period. Even though chlorhexidine is the one of the widely used agent for disinfection in hospital setting, Chlorhexidine gluconate (0.02%) was tested on animal coronavirus mouse hepatitis virus (MHV), and it was found to be ineffective.[25]

Conclusion

In the COVID era, the information obtained from different forms of media is scary and it builds unjustified apprehension. An effort was made through this review paper which presents human coronaviruses' sustainability on various surfaces under different conditions. Only a single paper presents about SARS-Cov-2 virus. Various bioactive agents are also presented out of which ethanol, 2-propanol and 1-propanol, hydrogen peroxide, glutaraldehyde, and povidone iodine was reported to be effective. There is a requirement for multiple supportive studies to unravel the mysterious SARS-CoV-2 virus. A global approach to deal with such virus would show the right avenue to combat it successfully.

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