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Review article

Contamination of inert surfaces by SARS-CoV-2: Persistence, stability and infectivity. A review

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A B S T R A C T

Undoubtedly, there is a tremendous concern regarding the new viral strain "Severe Acute Respiratory Syndrome Coronavirus-2" (SARS-CoV-2) and its related disease known as COVID-19. The World Health Organization has stated that SARS-CoV-2 is mainly transmitted from person-to-person close contact, as well as by small aerosol respiratory droplets. Moreover, the results of some recent studies about the role of air pollution on the spread and lethality of the novel coronavirus suggest that air contaminants could be also a transmission pathway of the virus. On the other hand, indirect transmission of the virus cannot be discarded. Among many sources of indirect transmission, there is the contamination of inert/inanimate surfaces. This manuscript was aimed at reviewing the scientific literature currently available in PubMed and Scopus. The results of the reviewed studies point out that SARS-CoV-2 can last on different surfaces from hours to a few days. However, rapid SARS-CoV-2 inactivation is possible by applying commonly available chemicals and biocides on inanimate surfaces. Consequently, although the presence of SARS-CoV-2 on inanimate surfaces can represent a potential route of transmission, appropriate disinfection measures should reduce the possibilities of coronavirus transmission, and hence, significantly decrease the risks of COVID-19.

1. Introduction

Nowadays, the potential transmission routes of the SARS-CoV-2 and the resulting infections are still not clear. However, the problem is not about the quantity of investigations that have been carried out. In November 21, 2020, the number of studies on COVID-19 available in PubMed (https://pubmed.ncbi.nlm.nih.gov/) raised to 76,103, with a continuous daily increase. The vast majority of documents have been published in 2020, with only a few papers belonging to 2019, while an increasing number are already dated in 2021. This scientific production is tremendously high when compared with other respiratory viruses, such as influenza. To date, there are 137,047 articles available at PubMed, which in turn have been published from the 19th century. Without any doubt, in the past no other disease has received so much attention in such a short space of time.

According to the World Health Organization (WHO, 2020a), SARS-CoV-2 is mainly transmitted through person-to-person close contact (<1.5–2.0 m), as well as by aerosol respiratory droplets smaller than 5 μm of diameter. Obviously, taking into account that SARS-CoV-2 is a respiratory virus, airways are key for the infection person-to-person (Rothan and Byrareddy, 2020). Moreover, several studies on the airborne transmission of this coronavirus have been also recently conducted (Buonanno et al., 2020; Morawska and Cao, 2020; Morawska et al., 2020; Yao et al., 2020a, 2020b). In particular, the transport of droplet aerosols generated by infected individuals is an issue of considerable concern and importance, which should be taken into account to reduce the risk of infections (Kohanski et al., 2020; Lee, 2020; Miller et al., 2020: Nissen et al., 2020; Zhou and Ji, 2021). On the other hand, recent studies on the role of air pollution on the spread and lethality of the coronavirus have also attracted a notable attention (Bontempi, 2020; Coccia, 2020; Copat et al., 2020; Domingo et al., 2020; Domingo and Rovira, 2020). It is hypothesized that certain air pollutants – mainly particulate matter ($PM_{2.5}$ and other small PMs) – can carry SARS-CoV-2 attached, which could be involved in the spread of COVID-19. In this sense, Setti et al. (2020a) raised the question whether 2 m of interpersonal distance would be enough to avoid the person-to-person transmission of the coronavirus. In recent months, a number of studies on this topic have been conducted (Adhikari and Yin, 2020; Comunian et al., 2020; Marquès et al., 2020; Setti et al., 2020b,c, d; Yao et al., 2020a, 2020b; Zoran et al., 2020).

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materials for protection from virus infection, while the risk of transmission via touching contaminated paper was low. Anyhow, because of the lack of information when that review was published, the authors recommended using preventive strategies such as washing hands and wearing masks for containing COVID-19. The importance of surface-mediated transmission, particularly in light of the current outbreak, was also demonstrated by Rawlinson et al. (2020), who used a DNA oligonucleotide surrogate for contaminated bodily fluid based on the cauliflower mosaic virus (AB863139.1) to determine how SARS-CoV-2 would spread within a clinical surface environment. The results showed that within 10 h, the surrogate moved from the isolation room and transferred to 41% of all surfaces sampled. That study highlighted the role of surfaces as a reservoir of pathogens and the need to address requirements for surface cleaning. In relation to this, since SARS-CoV-2 is an enveloped virus, according to the authors, it should be very susceptible to most cleaning agents. In another review on the persistence of infectious SARS-CoV-2 on inert surfaces, Gerlier and Martin-Latil (2020) corroborated the persistence of SARS-CoV-2 based on the results of the two studies that were available at that time: van Doremalen et al. (2020), which has already been discussed above, and Chin et al. (2020). The later measured the stability of SARS-CoV-2 at different temperatures and on different surfaces. No infectious virus was recovered from printing and tissue papers after a 3-h incubation. Also, no infectious virus was detected from treated wood and cloth on day 2. SARS-CoV-2 was more stable on smooth surfaces, but no infectious virus was found from treated smooth surfaces on day 4 (glass and banknotes), or on day 7 (stainless steel and plastic). Once again, SARS-CoV-2 was susceptible to regular disinfection methods. Carraturo et al. (2020), who stated that besides the high infectiousness of SARS-CoV-2, its transmission might be contained applying appropriate preventive measures such as personal protection equipment, and disinfecting agents, drew similar conclusions.

Using data from the scientific literature, Aboubakr et al. (2020) concluded that the persistence of SARS-CoV-1 and SARS-CoV-2 was significantly low on copper, latex and less porous fabrics in comparison to surfaces like metals (stainless steel and zinc), glass, and more porous fabrics. Interestingly, these authors suggested that using copper-made common touch surfaces in hospitals might help to reduce the persistence of SARS-CoV-2. On the other hand, this coronavirus could have different survivability on a single surface according to changes in temperature and relative humidity. Regarding this, Biryukov et al. (2020) investigated the effects of temperature, relative humidity, as well as droplet size on the stability of SARS-CoV-2 in a simulated clinically relevant matrix dried on non-porous surfaces. It was observed that SARS-CoV-2 decayed more rapidly when either humidity or temperature increased, but the droplet volume (1–50 μl) and surface type (stainless steel, plastic or nitrile glove) did not significantly impact on the decay rate. Therefore, a potential fomite transmission could persist for hours to days in indoor environments, having important implications to assess the risks of surface contamination. Recently, Morris et al. (2020) examined the effect of temperature and relative humidity on the stability of SARS-CoV-2 and other enveloped viruses. It was found that SARS-CoV-2 survived better at low temperatures and extreme relative humidity. The estimated median virus half-life was more than 24 h at 10 °C and 40% relative humidity, being approximately 1.5 h at 27 °C and 65% relative humidity.

In turn, Suman et al. (2020) reviewed the sustainability of coronaviruses on different surfaces, which were similar for SARS-CoV-1 and SARS-CoV-2. The infection decay chart for SARS-CoV-2 showed a linear decrease in its infection capability over time, and depending on the surface: plastic (72 h), stainless steel (48 h), copper (4 h) and cardboard (24 h). The alcohol-based disinfectants can reduce significantly the survival and decay time of SARS-CoV-2. On the other hand, Colaneri et al. (2020) investigated the presence of SARS-CoV-2 in samples of swabs collected from inanimate surfaces in an infectious disease emergency unit and in a sub-intensive care ward. Only two samples were positive for low-levels of SARS-CoV-2. All transport media were inoculated onto susceptible cells, but none induced a cytopathic effect on day 7 of culture. According to their results, daily contact with inanimate surfaces and patient fomites in contaminated areas could mean a medium of infection, but less extensive than it is currently considered.

Recently, Kampf et al. (2020b) extensively reviewed the potential sources and pathways of SARS-CoV-2 transmission. Regarding inanimate surfaces, data from hospitals were collected in order to describe the frequency of detection of SARS-CoV-2 on inanimate surfaces in the immediate patient surroundings. The detection rate was variable on surfaces (0–75%) of intensive care units (ICUs), in isolation rooms (1.4–100%), and on general wards (0–61%). The mean coronavirus concentrations per swab were 4.4–5.2 $\log_{10}$ on ICUs and 2.8–4.0 $\log_{10}$ on general wards. On cleaned and disinfected surfaces, viral RNA was rarely detected, while the presence of viral RNA on the floor could be indicative for sedimentation of contaminated droplets. For their part, Gerlach et al. (2020) assessed – on several surfaces – the efficacy of single components of disinfectants and household cleaning agents against SARS-CoV-2. The materials tested were the following: stainless steel, plastic, glass, polyvinyl chloride, cardboard and cotton fabric. SARS-CoV-2 remained viable on all surfaces throughout a dehydration period of 1 h, being the surface stability of the coronavirus in alignment with the previous results of van Dorelamen et al. (2020). No significant loss of infectivity on cotton fabric was noted, indicating SARS-CoV-2 persistence. Although SARS-CoV-2 is more stable on plastic and stainless steel, it was highly susceptible to 70% ethanol or isopropanol, for example, or also to 0.1% H_2O_2, within 60 s of exposure, independently of the contaminated surface. Recently, Xue et al. (2020) reviewed the stability of SARS-CoV-2 and similar viruses on surfaces, as well as those materials that might actively reduce SARS-CoV-2 surface contamination and its associated transmission. The authors concluded that although previous studies have shown that certain viruses survive longer on some surfaces compared with others (Vasickova et al., 2010), it is unclear the role of surface chemistry on viral survival, infectivity, and denaturation. In turn, the role of the local environment would be still unclear.

4. SARS-CoV-2 in banknotes and coins

In the past decade, Thomas et al. (2008) assessed the survival of human influenza viruses on banknotes, which had been experimentally contaminated with various influenza virus subtypes at several concentrations, being survival tested after different periods. It was found that infectious virus might survive for several days on banknotes. These results provided potential evidence that cash could mean a viral vector. However, it would require a relatively large inoculum and the presence of a protective matrix, such as respiratory mucus. Although another potential vector of transmission of SARS-CoV-2 could be paper money and coins, information is certainly limited. Recently, Ren and Tang (2020) hypothesized that during the COVID-19 pandemic, when people are infected by the virus, they could transmit it onto paper or coin money through touch and droplets, potentially making any physical currency a possible carrier of the coronavirus. Consequently, during cash circulation, SARS-CoV-2 might be spread among individuals, which would increase the chance of people to become infected by the coronavirus. Notwithstanding, these authors highlighted that – right now – there are no experimental studies corroborating that individuals could be infected with SARS-CoV-2 by cash circulation. Their hypothesis was mainly based on the results of van Doremalen et al. (2020) on the stability of the coronavirus in metals and paper. Similarly, Pal and Bhadada (2020) have summarized the possibilities of transmission of COVID-19 via currency. Two questions were discussed: i) does viral transmission occur through cash and coins?; and ii) which are the precautions and practices that can be followed when handling cash and coins? It was concluded that banknotes and coins should be considered as potential sources of transmission of SARS-CoV-2. However, these same authors also indicated the need of laboratory stimulation data that may help to