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Letter to the Editor

SARS-CoV-2: air/aerosols and surfaces in laboratory and clinical settings

Sir,

The pandemic of coronavirus disease 2019 (COVID-19) is known to be caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. Current evidence indicates that SARS-CoV-2 is mainly transmitted through respiratory droplets and close contact [1]. However, a report describing a cluster of COVID-19 cases in a shopping mall postulated the indirect transmission of SARS-CoV-2, potentially via surface contamination of common objects or virus aerosolization in a confined space or spread from asymptomatic infected persons [2]. Combined with previous reports implicating other coronaviruses in super-spreading events and nosocomial outbreaks [3], researchers are now investigating air/aerosol and fomite transmission as potential routes of transmission of SARS-CoV-2. As SARS-CoV-2 is novel, our understanding of its transmission characteristics remains limited. There are four recent studies representative of current investigation of SARS-CoV-2 in air/aerosols and on surfaces in laboratory and clinical settings [4—7].

Under laboratory experimental conditions, van Doremalen *et al*. assessed the stability of SARS-CoV-2 in aerosols and on different surfaces in comparison with that of SARS-CoV [6]. In general, SARS-CoV-2 and SARS-CoV shared similar stability properties in aerosols and on various surfaces. SARS-CoV-2 remained viable in aerosols for up to 3 h, and remained viable on different surfaces for longer periods ranging from 4 to 72 h. SARS-CoV-2 was most stable on plastic surfaces, followed by stainless steel, cardboard and copper surfaces. Moreover, the stability/viability of SARS-CoV-2 decreased over time in aerosols and on surfaces. In brief, the study highlights the similarity of SARS-CoV-2 and SARS-CoV in terms of stability and viability in aerosols and on different surfaces, the latter of which can be inactivated easily using common disinfectants [8]. This aspect of the two viruses enables us to revisit previous successful infection prevention and control (IPC) solutions in combating SARS with adaptation to the current COVID-19 situation. However, it should be noted that the viability and stability of SARS-CoV-2 in aerosols was evaluated under laboratory conditions, which may differ considerably from real-world clinical environments, and thus should be interpreted carefully. Further clinical investigations are required to characterize aerosol transmission as a potential route of transmission of SARS-CoV-2.

Three studies examined clinical settings. Ong *et al*. investigated the air and surface presence of SARS-CoV-2 associated with three patients in a COVID-19-delicated facility in Singapore, where routine cleaning was performed twice per day in patients' rooms [5]. Most pre-cleaning surface samples showed positive results while post-cleaning samples were all negative, suggesting that routine cleaning appears to be effective in containing surface contamination of SARS-CoV-2. All the air samples were negative. To extend the study cohort, Guo *et al*. included 39 patients in a COVID-19-specialized hospital in Wuhan, China, with 15 patients in the intensive care unit (ICU) and 24 patients on a general ward [4,5]. Sampling was performed between twice-daily routine cleanings. The ICU had more positive results than the general ward in both surface and air samples. This implies that more stringent IPC approaches should be considered in ICUs. Another clinical study found that SARS-CoV-2 lasted significantly longer with a higher viral load in the respiratory samples of patients with severe conditions than in those from patients with mild illness [9]. Another study by Liu *et al*. investigated the aerodynamics of SARS-CoV-2 at hospitals in Wuhan, China [7]. They found high levels of SARS-CoV-2 viral RNA in aerosols from protective apparel removal rooms for medical staff and a poorly ventilated mobile toilet room for patients. They also found that good ventilation and proper disinfection and sterilization protocols effectively restrained the concentration of SARS-CoV-2 RNA detectable in aerosols. Overall, these studies shed light on the aerosol and fomite dynamics of SARS-CoV-2 in the hospital setting [4,5,7]. However, quantitative polymerase chain reaction (PCR) was the only detection method for SARS-CoV-2 used in these studies [4,5,7], which only validated the presence of viral RNA without giving information about viral infectivity or viability. As viral stability/viability is of importance for IPC strategies, additional studies are needed to determine this aspect of SARS-CoV-2 using cultures in clinical settings.

From the perspective of airborne/aerosol transmission, inconsistent findings were observed in the above studies [4—7]. Hence, current evidence is insufficient to conclude whether this route of transmission is viable for SARS-CoV-2 [4—7] and further investigations are warranted. A Singapore-based case report showed that either surgical masks or N95 respirators provided sufficient protection for healthcare workers against SARS-CoV-2, even when aerosol-generating procedures were involved [10]. However, this case report was based on a single patient, and environmental contamination risks and IPC measures can vary considerably between institutions. Therefore, we should stay vigilant and not be deterred from proper

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aerosol precautions. To illustrate, many current guidelines and recommendations prioritize respirators such as N95 respirators for aerosol-generating medical procedures as we are facing significant shortages of such personal protective equipment (PPE) [11,12]. Additional studies elucidating which medical procedures pose higher aerosol risks will help decision-making.

With regard to fomite transmission, surface contamination hotspots where virus-laden droplets tend to deposit warrant extra attention. Examples include air exhaust outlets and vents, and patient toilet rooms [4,5]. Swab samplings from toilet bowls and sinks in patients' rooms tested positive [5], and other studies have reported the presence of viral RNA in faecal samples and evidence of suspected gastrointestinal infection [7,13,14]. The shoes of healthcare workers and the floor represent other hotspots. For example, the Singapore-based study found a swab sampling from the surface of a shoe front tested positive when other PPE samples tested negative [5]. Consistent with this, the Wuhan-based research team found that half of the samples taken from the soles of shoes of ICU staff were positive [4]. Furthermore, all the samples from the pharmacy floor were positive; as patients do not have access to the pharmacy, this implies that the virus may be tracked around on the floor through the shoes of healthcare workers [4]. Thus, the frequency of cleaning can be increased for identified contamination hotspots, and disposable shoe covers or disinfection for the soles of shoes may be incorporated into contamination control measures.

Although the accumulation of the virus in hotspots may be troublesome, coronaviruses can be inactivated easily using common disinfectants containing adequate concentrations of biocidal agents, such as ethanol, sodium hypochlorite and hydrogen peroxide [15,16]. In addition, ultraviolet (UV) germicidal irradiation has been proposed to inactivate SARS-CoV-2 [17]. However, disinfectants and UV germicidal irradiation are reserved for the disinfection of inanimate surfaces alone. It should be made clear to the general public that ingestion or injection of surface disinfectants or skin sterilization using UV irradiation is dangerous and should be strictly prohibited, despite mixed information from various sources.

When it comes to containing surface contamination, we are encouraged to take local environmental contamination factors at institutions, such as surface exposure to virus-laden droplets and surface materials, into consideration and make the cleaning and disinfection protocols more context-specific, including frequency and timing of cleaning and selection of disinfectants, as the above studies suggest a differential stability/viability profile of SARS-CoV-2 on various surfaces, imbalanced viral distribution between ICUs and general wards, and preferential accumulation of virus in hotspots [4—6].

In addition to the potential for spread via aerosols and surfaces, pre-symptomatic and asymptomatic transmission have been recognized to contribute to the rapid and broad spread of SARS-CoV-2 in healthcare settings. Arons *et al*. performed a thorough investigation into the spread of SARS-CoV-2 in a skilled nursing facility in the USA, and emphasized the importance of pre-symptomatic precautions in IPC strategies [18]. Over half of the facility residents whose results returned positive, as detected by quantitative PCR, did not show symptoms when tested. More importantly, viable virus was isolated from samples of pre-symptomatic residents. This implies that shedding of viable virus by pre-symptomatic residents may contribute to rapid and extensive transmission of SARS-CoV-2 in nursing facilities. As the authors concluded, in healthcare settings, symptom-based IPC strategies are insufficient and ineffective to contain transmission. Thus, more proactive IPC measures should focus on preventing the spread from asymptomatic and pre-symptomatic infections, such as limiting access to essential personnel alone, and expanding the scale of quantitative PCR-based testing for staff and patients. Implementing a universal mask-wearing policy in healthcare facilities can be useful, as a recent visualization experiment demonstrated that covering the face significantly reduced the count of forward-moving droplets when speaking [19] and may reduce droplet-associated risks.

In summary, IPC in clinical settings is crucial to winning the battle against SARS-CoV-2, as the emergence of this invisible enemy has posed unprecedented threats and challenges to public health worldwide. Recent studies have equipped us with several IPC key points in controlling aerosol- and fomite-associated risks. With respect to potential air/aerosol-associated risks, we should exercise vigilance and proper precautions, although current evidence is insufficient to determine the potential of airborne or aerosol transmission [4—7]. For instance, respirators such as N95 respirators are recommended for aerosol-generating medical procedures by various guidelines [11,12], and we need to offer adequate room ventilation plus appropriate disinfection and sterilization to effectively limit levels of SARS-CoV-2 RNA in aerosols [7]. In terms of fomite transmission, routine cleaning is effective in containing surface contamination of SARS-CoV-2 [5], and many common disinfectants as well as UV germicidal irradiation can be used to inactivate the virus effectively [15—17]. Moreover, we should make IPC protocols more context-specific by considering local environmental contamination factors, as the virus exhibits differential viral viability dynamics on various surfaces and imbalanced viral distribution between environments. More stringent IPC approaches, including more frequent surface cleaning, should be considered for ICUs and other surface contamination hotspots, such as air exhaust outlets/vents, patient toilet rooms and the shoes of healthcare workers [4,5]. Apart from potential transmission via aerosols and surfaces, pre-symptomatic precautions are crucial to prevent and control viral spread in healthcare settings, as emerging evidence has shown that pre-symptomatic patients can shed viable virus and contribute to nosocomial infections [18]. Key pre-symptomatic precaution measures include limiting access to essential personnel alone, expanding quantitative PCR-based testing for staff and patients, and implementing universal mask-wearing policies in healthcare facilities. Despite the above, our understanding of the transmission dynamics of SARS-CoV-2 remains incomplete. As we gain information, timely exchange of knowledge and experience is highly beneficial and essential for successful containment of COVID-19 in healthcare settings worldwide.

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