Transmission of SARS-CoV-2 via Contaminated Surfaces: What is to be Done?

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Within a short period after COVID-19 cases were first identified, it became apparent that SARS-CoV-2 spread more easily than SARS-CoV-1, especially in community settings. Some experts believed that SARS-CoV-2's increased propensity to spread could be due to indirect and direct contact transmission involving contaminated environmental surfaces and hands [i]. This stance was reinforced by media images of large scale spraying of disinfectant in outdoor public spaces in Asia, and postings on social media, such as a YouTube video demonstrating how to disinfect groceries, viewed over 26 million times [ii]. This early focus on contact transmission may have diverted our focus from emphasizing the importance of masking in the community. But it was not unreasonable, based on the lack of complete understanding about how other coronaviruses are transmitted and current (but also less than complete) understanding about transmission of other respiratory viruses [iii,iv]. According to Mandell, "...direct contact appears to be the most efficient" mode of transmission of rhinoviruses, and the CDC states that "(t)he flu virus can 'live' on some surfaces for up to 48 hours. Routine cleaning of surfaces may reduce the spread of the flu." [v,vi]

In this issue of *Clinical Infectious Diseases*, Kanamori *et al.* provide an overview of the current literature on the role of surfaces in transmission of SARS-CoV-2 in healthcare settings [vii]. Findings in this domain must be interpreted with caution for numerous reasons. First, this is an area of active investigation, and the evidence base at any given point in time is incomplete--more is still to be learned. Second, real world conditions (e.g. inoculum size, temperature and humidity) are often not replicated in controlled, laboratory based experiments [viii]. Third, use of PCR techniques to evaluate contamination of surfaces is problematic, as PCR does not distinguish between live and dead virus. And fourth, SARS-COV-2 culture-based studies in clinical settings are infrequent, and when conducted, use different protocols for sample collection (e.g timing, culture conditions) and typically do not control for patient attributes (e.g. viral load, duration of illness).

Given these limitations, what are key takeaways based on studies to date?

1. Variable degrees of SARS-CoV-2 contamination of surfaces in healthcare settings can be demonstrated using PCR, for periods ranging from hours to days, depending on temperature, humidity, and the type of surface [ix].
2. After placing large inocula on surfaces, SARS-CoV-2 can be cultured for up to a week in experimental settings, with rapid decay in the quantity of viable virus over time [x,xi].
3. Despite successful culture of SARS-CoV-2 specimens from environmental surfaces under experimental conditions, efforts to culture live virus from surfaces in clinical settings have been largely unsuccessful, except in two recently reported studies involving ICU patients [xii,xiii]. In one study, virus was successfully cultured from environmental surfaces in a room where the patient "spat out" frequently, and in the other, results suggested that replication competent virus was present in some environmental samples, although cultivation of virus was not confirmed.

4. Although some reports have postulated that fomites or direct contact are potentially responsible for SARS-CoV-2 spread, no studies to date have definitively demonstrated healthcare-associated transmission via environmental surfaces or healthcare workers' hands [xiv,xv,xvi]. However, making the distinction between respiratory and contact transmission is not straightforward, as shared air space between cases and contacts makes exclusion of respiratory transmission difficult. Experts believe that transmission can occur through touching surfaces contaminated with virus from an infected person followed by touching the mouth, nose, or eyes, but this viewpoint is interpreted differently. For example, the European Centers for Disease Control (ECDC) considers shaking hands with a case to be a "high risk exposure" and "close contact", but direct contact such as shaking hands is not included among CDC criteria for close contact (although CDC does recommend not shaking hands during social activities) [xvii,xviii,xix].

5. SARS-CoV-2 has a lipid envelope, making it easier to deactivate with disinfectants than other pathogens (e.g. non-enveloped viruses, vegetative bacteria) [xx,xxi]. (Soap or detergent along with warm water should also contribute to disinfecting surfaces contaminated with SARS-CoV-2, although this is not well studied [xxii,xxiii]. Even if SARS-CoV-2 remains viable, at least briefly, on environmental surfaces, studies using PCR indicate that the virus is not detectable after disinfection using proper products and processes [xxiv,xxv]. CDC recommends use of a disinfectant with an "emerging viral pathogen" claim to prevent healthcare-associated transmission of SARS-CoV-2 [xxvi]. This is a higher standard than required by EPA for inclusion on its N-list, as this claim means the disinfectant is effective against a harder-to-kill virus than SARS-CoV-2. Given the array of nosocomial pathogens for which disinfection should be performed, a "horizontal" approach to disinfection that eliminates other pathogens in addition to SARS-CoV-2 is sensible.

In order to further advance our understanding of risks associated with contaminated surfaces, and allow healthcare facilities to target resources more efficiently and effectively, gaps in our knowledge about transmission due to environmental contamination and contact transmission should be addressed. Key issues for future investigations include:

- Determination of the infectious dose of SARS-CoV-2 based on exposure via different routes. With this information, the implications of studies that demonstrate and quantitate surface (as well as air) contamination with viable virus can be more meaningfully interpreted.

- Better standardization of methods used for studies of surface contamination, in order to facilitate objective comparison of results [xxvii,xxviii]. This is a complex task as process steps (collection, transport, recovery, and culture) depend upon a variety of factors (e.g. surface type and whether qualitative or quantitative results are sought) [xxix]. In addition, host factors (e.g. viral load, duration of illness) may have a significant impact on natural history study results.

- Definitive information about survival of viable virus from respiratory and non-respiratory sources on various environmental surfaces in "real-world" healthcare settings. If viable virus is detectable on certain environmental surfaces, quantification of the duration of viability will have important practical implications. For example, if viable virus is present on environmental surfaces, in a patient's room for only 20 minutes after a patient has been discharged, enhanced environmental cleaning and disinfection practices currently in use at many facilities could be scaled back.

- Prospective studies focused on risk factors for nosocomial acquisition of SARS-CoV-2. Such studies were rarely performed during the initial pandemic wave, as healthcare facilities were focused on other priorities. Going forward, high quality clinical trials, cohort, and case-control studies that combine laboratory and epidemiologic approaches can provide high quality evidence for decision making. Without rigorous assessment of exposures and accurate classification of which COVID-19 cases occurring in healthcare workers are acquired in the community vs. nosocomially, the role of the healthcare surface environment in transmission will remain ambiguous. Genetic sequencing of specimens from infected healthcare workers and their contacts (healthcare and non- healthcare) will allow more accurate determination of which COVID-19 cases among are *not* nosocomially acquired, and therefore not due to surface contact (or respiratory) transmission in the healthcare setting [xxx]. The risk of transmission of SARS-CoV-2 from N-95 respirators also needs further investigation. Substantial resources are currently being expended on bulk reprocessing techniques using vaporous hydrogen peroxide, ultraviolet germicidal irradiation, and heat, and it should be determined if such "high tech" methods are necessary [xxxi]. If viable virus is not present after a short period (e.g. less than 8-12 hours) post N-95 use, practices that are less costly, less resource intensive, and have less impact on respirator structural integrity and performance can be widely implemented--for example, simply storing the respirator in a paper bag or box for the appropriate interval between shifts [xxxii].

Although the role of environmental cleaning and disinfection in community (non-healthcare) settings is not the subject of Kanamori *et al*.'s review, better evidence in this area is also critical to inform decision making in settings such as schools, workplaces, and public transport. In schools, for example, cases typically lead to disruptive closures, especially since the CDC advises leaving a room empty for 24 hours before cleaning takes place. Nightly cleaning of the New York City subway is reportedly on pace to cost $100 million this year, and it is unclear if this expenditure is necessary [xxxiii].

Although our understanding is still incomplete, the balance of evidence to date does not support environmental surface contamination as a key driver of SARS-CoV-2 spread. Based on common sense and available data, the likely sequence of events required for transmission related to surface contamination to occur--viable virus being present on a surface, survival of the virus until the surface is touched, and transfer of the virus to the eyes, nose, or mouth due to hands contaminated with an infectious dose of virus—is unlikely to occur in healthcare settings where hand hygiene is performed and PPE is used as recommended. Nevertheless, details matter, and further advances in our understanding of potential transmission mechanisms involving direct and indirect contact will improve pandemic response. Most importantly, these advances will enable healthcare facilities to protect workers, patients, and others against SARS-COV-2 through optimally effective and proportional preventive measures.

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