COVID-19 Evidence Update

COVID-19 Update from SAHMRI

23 August 2021

Fomite Transmission of SARS-CoV-2 – Supplement

Executive Summary

This review is a supplement to the *COVID-19 Evidence Update: Fomite Transmission of SARS-CoV-2 (29 October 2020)* and updates the available evidence on detection of virus and potential transmission via surfaces.

Overview: Several laboratory studies demonstrated that inanimate surfaces can be contaminated with SARS-CoV-2 RNA which remains viable for varying time periods. Multiple real-world studies have detected SARS-CoV-2 RNA on surfaces; however virus is rarely found to be viable (i.e. able to be cultured in a lab). Despite the widespread evidence of detectable virus on surfaces, there are very few case studies and no direct evidence of fomite transmission where other sources of transmission can be confidently ruled out. Since the past review, there has been an expansion of evidence, but **the published evidence continues to indicate that, while possible, fomite transmission is unlikely to be a major contributor to transmission.**

State of the evidence: Since the original Evidence Update, there have been multiple reviews of the evidence, as well as new primary case studies, new observational environmental detection studies, and expert summaries.

Summary of new evidence:

- A living review ([1]; last updated 14 June 2021) identified 63 primary studies investigating the detection of SARS-CoV-2 RNA on surfaces, most frequently in hospitals but also in laboratories and households. The frequency of positive tests for SARS-CoV-2 RNA from RT-PCR tests ranges from 0.5% to 75% (Ct values from 20.8 to 44.1), and was highest in residential isolation rooms. Of the 11 studies that planned to culture the virus to determine viability, none were successful. The review authors concluded that the despite majority reporting of detection of virus on surfaces, **lack of positive viral cultures suggests that the risk of transmission of SARS-CoV-2 through fomites is low.**
- Two other reviews [2, 3] reported on studies that have attempted to culture the virus from SARS-CoV-2 RNA obtained from environmental swabs. From the 9 included studies, 3 have reported detecting viable virus in high-risk settings (i.e. isolation rooms; [4-6]).
- One additional primary study [7] reported viability (via monitoring of cell cultures for virus-induced cytopathic effects) of SARS-CoV-2 RNA found in household settings. Of 23 (15%) positive samples, cytopathic effects were observed for 1 sample, that came from a nightstand swab (Ct=26.4).
- There are additional reports of case studies in real world settings where fomite transmission was a possible source, although in most cases, aerosol transmission could not be ruled out.

Executive Summary from *Fomite Transmission of SARS-CoV-2 (29 Oct 2020)*

This review covers the available evidence on SARS-CoV-2 survival, contamination and transmission via environmental surfaces (including domestic pets) as well as SARS-CoV-2 surface inactivation.

***State of the evidence**: The search yielded 151 references, of which 78 were considered in-scope. Of the literature summarised here, 66% were peer-reviewed article, 8% were correspondence (e.g. research letters, commentaries) and 26% were pre-print. The literature was supplemented with an informal online search for media or governmental reporting of cases of fomite transmission of SARS-CoV-2.*

***Overview:** Several laboratory studies have demonstrated that inanimate surfaces can be contaminated with SARS-CoV-2 which remains viable for varying time periods. Further, real world studies have detected (non-viable) viral RNA on surfaces. Despite this, there is **no direct evidence of fomite transmission** where other sources of transmission can be completely ruled out, and only 4 case studies of probable transmission. The published evidence indicates that, while possible, fomite transmission is unlikely to be a major contributor to transmission.*

***Case studies**: Authors in eight studies identified fomites as a possible transmission source but noted they could not rule out other potential sources. **One published case report** from China indicates one likely case of transmission via fomite (apartment lift button contaminated with nasal mucus) [8]. **One published study** from South Korea identified an on-board toilet as the suspected source of transmission on an evacuation flight [9]. Media reports from New Zealand, discuss **two case studies** of likely fomite transmission reported by the NZ Government from **within hotel quarantine** – one from a lift button, another from a rubbish bin lid.*

***Systematic reviews on transmission**: Meyerowitz et al. [10] conducted a comprehensive and systematic review of the transmission of SARS-CoV-2 from a range of sources (including fomites) and reported that **the dominant route is through droplets via close contacts**. **There is currently no conclusive evidence for fomite or fecal-oral transmission in humans**. Live virus can be detected on surfaces, both in real-world and laboratory settings, but whether the virus detected can cause infection remains unknown. On the basis of the current evidence, it is suspected that "the levels of viral RNA or live virus transiently remaining on surfaces are unlikely to cause infection". Similar conclusions were reported in another systematic review [11].*

***Stability of SARS-CoV-2 on surfaces**: A systematic review indicated that SARS-CoV-2 has short persistence on copper, latex and low porous surfaces compared to surfaces such as stainless steel, plastics, glass and highly porous fabrics, and is sensitive to temperature and humidity [12]. The number of hours/days that viable virus can be detected ranges across studies. For example, viable SARS-CoV-2 RNA has persisted on stainless steel for 3 days [13], 4 days [14], 7 days [15] and 28 days [16]. Differences are likely due to experimental conditions such as temperature, relative humidity, light, and initial viral load.*

***Contamination rate**: The proportion of samples where SARS-CoV-2 RNA can be detected in hospital and home settings ranges across studies. None of the studies could detect infectious SARS-CoV-2 from their samples.*

- *A systematic review found that the detection rate of SARS-CoV-2 RNA on inanimate hospital surfaces was variable: ICU surfaces (0% - 75%), in isolation rooms (1.4% - 100%) and on general wards (0% - 61%) [11]. The same study reported that viral RNA was detected in 3.4% of 119 surface samples in 21 households of confirmed COVID-19-cases and on 7.7% of sampled surfaces around COVID-19-cases in Italy, however, infectious SARS-CoV-2 was not found in any sample.*
- *A review found that the contamination rate of the healthcare environment with SARS-CoV-2 varies from 0-75% (median 12.1%), depending on the status of cleaning/disinfection in environmental sampling rather than the symptomatic status of COVID-19 patients [17].*

***SARS-CoV-2 surface inactivation**:*

- *Temperature and relative humidity are major factors determining virus inactivation in the environment; best conditions for coronaviruses inactivation were obtained at humidity 50% and at high temperature (>40 °C) [18].*
- *SARS-CoV-2 on surfaces can be inactivated by using range of common cleaning products (e.g. ethonol, 2-Propanol, hydrogen peroxide, benzalkonium chloride, sodium hypochlorite, sodium laureth sulphate).*

Limitations of the evidence

- *The precise source of most transmission events cannot be known due to overlapping risk factors (e.g. exposed to respiratory droplets and surface contamination) [10].*
- *Reports of fomite transmission would be more likely to come from places where there is extensive contact tracing and no community transmission.*
- *PCR for RNA of SARS-CoV-2 does not distinguish between infectious virus and non-infectious nucleic acid. Thus, interpretation of duration of viral shedding and infection potential should be based on viable virus from cell culture and needs to be carefully evaluated when solely based on PCR results [11].*
- *There are no studies investigating the extent that fomites are related to super-spreading events, which are increasingly recognised as the main distribution pattern of SARS-CoV-2.*

Health Agency advice

- ***World Health Organization**: Although fomites and contaminated surfaces have yet to be conclusively linked to transmission of SARS-CoV-2, demonstration of surface contamination in healthcare settings and experiences with surface contamination linked to subsequent infection transmission in other coronaviruses, have informed the development of cleaning and disinfection recommendations to mitigate the potential of fomite transmission.*
- ***US Centers for Disease Control and Prevention**:*
  Respiratory droplets can also land on surfaces and objects. It is possible that a person could get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or eyes.
  Spread from touching surfaces is not thought to be a common way that COVID-19 spreads

Suggested citation: Miller C, Dono J, Wesselingh S. (2021) Fomites and Transmission of SARS-CoV-2 (Supplement). SAHMRI. https://www.sahmri.org/covid19/

Published Reviews

[1] Onakpoya et al. (2021, F1000 Research) Living review, latest update published 14 June 2021

- Objective was to identify, appraise and summarise the evidence from primary studies and systematic reviews assessing the role of **fomites in transmission**
- Searched: WHO Covid-19 Database, LitCovid, medRxiv, and Google Scholar
- Results: found 64 studies: 63 primary studies and one systematic review (n=35). The settings for primary studies were predominantly in hospitals (69.8%) including general wards, ICU and SARS-CoV-2 isolation wards. There were variations in the study designs including timing of sample collection, hygiene procedures, ventilation settings and cycle threshold. The overall quality of reporting was low to moderate. **The frequency of positive SARS-CoV-2 tests across 51 studies (using RT-PCR) ranged from 0.5% to 75%.** Cycle threshold values ranged from 20.8 to 44.1. Viral concentrations were reported in 17 studies; however, discrepancies in the methods for estimation prevented comparison. **Eleven studies (17.5%) attempted viral culture, but none found a cytopathic effect.** Results of the systematic review showed that healthcare settings were most frequently tested (25/35, 71.4%), but laboratories reported the highest frequency of contaminated surfaces (20.5%, 17/83).
- Conclusions: The majority of studies report identification of SARS-CoV-2 RNA on inanimate surfaces; however, there is a lack of evidence demonstrating the recovery of viable virus. **Lack of positive viral cultures suggests that the risk of transmission of SARS-CoV-2 through fomites is low.** Heterogeneity in study designs and methodology prevents comparisons of findings across studies.
- Cited studies:
    - Systematic review: [19] **Bedrosian** et al. 2020 reported on 35 studies, all tested for presence of SARS-CoV-2 RNA, but **no study assessed viral infectivity or viability**. Surface contamination was greatest in laboratories and least in households.
    - Primary studies (n=63)
        - In 59 studies (96.7%), fomite transmission was examined in high-frequency touch surfaces. Other surfaces included circulating banknotes, disposable chopsticks, hospital staff PPE.
        - The frequency of positive SARS-CoV-2 tests across 51 studies (via RT-PCR) ranged from 0.5% to 75%; 12 studies (19%) reported no positive tests. The highest frequency of positive tests was found in residential isolation rooms.
        - Of the 11 studies that planned to perform viral culture, only two (18.2%) reported Ct values that could act as prompts to undertake viral isolation. None of the studies reported success with viral culture despite positive RT-PCR detection tests. There were methodological issues with the techniques employed for viral culture across the studies. [Studies: [20] Ben-Shumel 2020, [21] Colaneri 2020a, [22] Dohla 2020, [23] Feng 2020, [24] Moore 2020, [25] Ong 2020, [26] Peyrony 2020, [6] Santarpia 2020, [27] Suzuki 2020, [28] Wang 2020a, [29] Zhou 2020]

[2] Belluco et al. (2021, European Journal of Epidemiology)

- Aimed to estimate SARS-CoV-2 prevalence on inanimate surfaces, identifying risk levels according to surface characteristics. A meta-analysis and a metaregression were carried out to quantify virus RNA prevalence and to identify important factors driving differences among studies.
- Searched: PubMed and Embase, last search conducted on 1 September 2020
- Found 40 articles, of which 32 assessed SARS-CoV-2 RNA. Twenty-nine out of 32 articles were fully carried out in healthcare facilities where a known source of contamination (infected patients) was present. Emergency departments, isolation rooms and intensive care units were the most frequently investigated areas.
- Across all studies overall, SARS-CoV-2 RNA was detected on surfaces with a prevalence of 0.085 (CI95 [0.042–0.138]). When surfaces were assigned different 'risk of contamination' categories (high, medium and low), SARSCoV-2 RNA was detected with a prevalence of 0.22 (CI95 [0.152–0.296]), 0.04 (CI95 [0.007–0.090]) and 0.00 (CI95 [0.00–0.019]), respectively.
- Duration of exposure greatly influenced the prevalence rate, whereas virus source and location of surface were significant in the single moderator models, losing significance in the multivariate model accounting for all moderators.
- Among the retrieved studies, only six assessed SARS-CoV-2 viability and only three detected viable virus [[4] Ahn et al. 2020, [5] Cheng et al. 2020, [6] Santarpia et al. 2020]. In those studies that detected viable SARS-CoV-2, the analysed surfaces were all classified as high-risk. Only one study analyzing high-risk surfaces did not detect viable SARS-CoV-2 on any surfaces [[29] Zhou et al. 2020]. Studies analyzing low-

and medium-risk surfaces did not report any viable SARS-CoV-2, despite the fact that some surfaces were RT-PCR positive [[21] Colaneri et al. 2020, [30] Yamagishi et al. 2020, [29] Zhou et al. 2020].

[3] Goncalves et al. (2021; Science of the Total Environment)

- Aim was to summarize the existing studies in which SARS-CoV-2 has been detected on inanimate surfaces.
- Searched: PubMed/MEDLINE and Scopus, up to 24 Feb 2021.
- Results: found 37 studies. 26 studies were conducted in hospital settings (n=3077 samples collected, 17.3% of the samples tested positive for SARS-CoV-2 RNA) and 13 studies were conducted in non-hospital settings (n=1724 samples collected, 10.1% tested positive).
- Six studies evaluated the viability/infectivity of SARS-CoV-2 from positive surface samples. A total of 242 positive samples were tested but no virus could be isolated from these samples. [Studies: [20] Ben-Shmuel et al., 2020; [21] Colaneri et al., 2020; [31] Lednicky et al., 2021; [32] Moreno et al., 2021; [6] Santarpia et al., 2020; [30] Yamagishi et al., 2020]
- Authors' note: Due to the lack of Biosecurity level 3 facilities, viability testing for SARS-CoV-2 recovered from surfaces remain scarce, and consequently it is not yet possible to assess the potential for transmission via surfaces.

[33] Hosseini et al. (2021, Current Opinion in Colloid & Interface Science)

- Narrative review of SARS-CoV-2 RNA on public surfaces. Summarises some of the results of sampling for viral RNA by the PCR technique, which can only give a total of RNA present and cannot discriminate between virus that has been inactivated and virus that can infect human cells. Noteworthy findings:
    - Chia et al. detected the SARS-CoV-2 RNA in hospital rooms where COVID-19 patients were kept. The most likely places to be contaminated were the floor (65%), followed by the air exhaust vent (60%), bed rail (59%), bedside locker (47%), cardiac table (~40%), electrical switch (~34%), chair (~34%), and toilet seat and flush (~28%). Found higher rates of contamination in the first week of illness compared to subsequent weeks.
    - Ong et al. tested high-touch surfaces in the hospital rooms of three COVID-19 patients. The researchers tested 28 surfaces. Prior to cleaning, RNA was detected on 61% of the surfaces. Subsequent to cleaning with sodium dichloroisocyanurate, RNA was not detected on any surface.
    - Harvey et al. explored the presence of virus in **public places** over 2 months (from April to June 2020). They checked **door handles, gas pump handles, ATM keypads, garbage cans, crosswalk buttons in essential businesses** (i.e. grocery stores, banks, gas stations, restaurants, laundromats, and a few more). They found that **8.3%** of 348 tested objects had positive results. The most contaminated surfaces were a **trash can handle** and a **liquor store door handle**. The percent of **contaminated surfaces decreased when temperature increased**.
    - Fernandez-de-Mera et al. also reported the detection of viral RNA on high-touch items in public spaces. They investigated 14 surfaces in public sites, including pharmacies, post offices, supermarkets, a police station, a city hall, and a few more. They reported that **21.4%** (3 out of 14) of the tested surfaces had positive results.
- Also summarises lab studies on virus stability on common solids.

[34] Azuma et al. (2020; Environmental Health and Preventive Medicine)

- Narrative review of environmental factors involved in SARS-CoV-2 transmission.
- Includes lab studies that report on the stability of fomites on surfaces (includes same studies as Marzoli 2021 below).
- Summarises key case studies investigating environmental factors as source of transmission - poor ventilation and close proximity in confined spaces were identified as facilitators of transmission.
    - Restaurant in Guangzhou, China - poor ventilation most likely the primary cause of spread.
    - Call center in Seoul, South Korea - contact time identified as a major factor.
    - Washington State Squadron practice (choir), United States of America - aerosols released during singing, or close contact possible reasons for high secondary infection rate.
    - Meat-processing plant in North Rhine-Westphalia, Germany - poor ventilation, high physical workload of workers with heavy breathing, identified as factors contributing to transmission.

[35] Marzoli et al. (2021, Science of the Total Environment)

- Objective: review literature on "How long can coronaviruses survive on different surfaces?". Review included multiple viruses, including SARS, MERS, SARS-CoV-2
- A total of 18 studies were found, 8 of which assessed SARS-CoV-2.

- The longest SARS-CoV-2 survival demonstrated under laboratory conditions at RT is 28 days on glass, steel and both polymer and paper banknotes. Low temperature and moisture can increase virus survival, while UV light and sunlight can substantially decrease virus survival on exposed surfaces.

Other reviews covering the same studies: [36] Marques et al. 2021, [37] Choi et al. 2021; [38] Fiorillo et al. 2020, [39] Fernandez-Raga et al. 2021, [40] Bueckert et al. 2020, [41] Aydogdu et al. 2021, [42] Chi et al. 2021, [43] Guo, et al. 2021.

New primary case studies

[44] Horoho et al. (2020, Military Medicine)

- Presents three active duty cases from deployable squadrons aboard **Naval Air Station (NAS) Jacksonville**, FL, which afford multiple opportunities for fomite transmission of COVID-19 in the aviation environment. Testing for all patients was performed with polymerase chain reaction nasopharyngeal swabs.

TABLE I. Summary of Case Series Demographics and Symptoms

	Case 1	Case 2	Case 3
Age/gender	22/female	20/male	19/male
Symptoms	Congestion, headache, cough, myalgia, dyspnea, and left rib pain	Headache and subjective fever	Burning sensation in chest, headache, congestion, anosmia, and ageusia
Exposure	Public restaurant	Geedunk, public beach, restaurant, and shopping center	Geedunk, public beach, restaurant, and shopping center
CDC close contacts	9	203	203
Downstream positives	1	0	0

- Case 1: She had recently returned from a shipboard deployment at sea on Friday, June 12, 2020, to Jacksonville, FL, her home duty station. The ship was in a clean bubble without any known COVID-19 infections during her entire time at sea. The following night, Saturday June 13, 2020, she went out to dinner with two of her friends from different commands at a public restaurant. Three days later (Tuesday, June 16, 2020), she began exhibiting symptoms but continued to work until Thursday, June 18, 2020. One of the nine close contacts tested positive on June 22, 2020, and this individual was noted to be friends with case 1 and spent time with her outside of work. The rest of the exposures were close contacts from work. During her 2 days at work while having symptoms, she handled numerous pieces of survival equipment, including a flight helmet, that were subsequently handled by others and did not lead to any downstream positive cases.
- Cases 2 and 3 were roommates: During the 48 hours preceding the appearance of symptoms, both patients worked as cashiers in the geedunk (a 15-by-15-foot room where the attendants handle cash, credit cards, and food items and make coffee that is available for self-service. Interactions between the attendants and customers are brief and occur within approximately 3 feet.) and spent time at the local beach, restaurants, and a shopping center. Eight individuals met the CDC close contact criteria for testing and an additional 195 personnel were tested twice over the course of 3-7 days because of concern for exposure in the geedunk while in a deployment status. **Despite the large number of tested individuals, no new positive cases were identified.**
- During the time of these cases, social distancing, masking, and sanitizing were in practice and may lend further support to their continued use and value.
- The authors conclude that **fomite spread may not be as large of a factor in transmission as was originally thought**.

[45] Eichler et al. (2021, Emerging Infectious Diseases)

- Evidence of Transmission in Hotel-Managed Isolation and Quarantine (MIQ)
- The MIQ facility was a repurposed commercial hotel, in which each room had its own bathroom and no balconies. Case-patient C was positive on day 12 and was relocated to the isolation section of the facility. Before their relocation, an adult and infant child, both of whom had returned from India on the same flight, were in the adjacent room (case-patients D and E)

- "Closed-circuit television review of the period between the arrival of case-patients C, D, and E and the transfer of case-patient C to the isolation section of MIQ showed that there were no instances where the 3 persons were outside of their rooms at the same time. Nevertheless, footage showed that during routine testing on day 12, which took place within the doorway of the hotel rooms, there was a 50-second window between closing the door to the room of case-patient C and opening the door to the room of case-patients D and E. Therefore, we hypothesized that suspended aerosol particles were the probable mode of transmission in this instance, and that the enclosed and unventilated space in the hotel corridor probably facilitated this event (4). A commissioned review of the ventilation system found that the rooms in question had a net positive pressure compared with the corridor. **Fomite transmission through use of communal bins in the corridor was considered to be a less probable route of transmission** because contact with the bin lid by case-patient D was >20 hours after it was touched by case-patient C.
- *[Note: at the time of the original Evidence Update, this **NZ case study** had significant international media reporting as evidence of fomite transmission, and that has since been **determined not to be the case**]*

[46] Brlek et al. (2020, Epidemiology and Infection)

- A cluster of five COVID-19 cases linked to **playing squash at a sports venue** in Maribor, Slovenia. Index patient (person A) was travelling in Italy from 29 February to 2 March, where he most likely acquired the infection. He developed symptoms of the disease (tiredness and fatigue) on 4 March during a game of squash. Later epidemiological investigations linked four other cases of COVID-19 to the same squash hall.
- Person A played squash with person B, arriving at the sports venue just before 17:30, used the dressing rooms and squash court, and left before 19:00. Person A began exhibiting symptoms later the same day. Person B developed symptoms a few days later. Person C and Person D arrived at 19:10, used the dressing rooms and squash court, talked to Persons E and F in the hallway, and left at 20:30. Persons E and F arrived at 19:50 and used the dressing rooms and squash court and left at 21:00. Persons C, D, E and F tested positive a few days later.
- It could not be confirmed whether all three pairs changed in the same dressing room, but all of them reported playing in the same squash hall. None of them shared any sport equipment and had no contact with the receptionist or any other employee at the sports venue.
- It is unlikely that the persons identified in the cluster were infected from different sources as there was no community spread at the time.
- "We concluded that the mode of transmission between the index patient and the secondary cases in this cluster was **either through contaminated common objects or virus aerosol**, since all three pairs shared the same squash hall, which is a small and confined space with poor ventilation, where strenuous physical activity is performed, during which shedding and aerosolisation of the virus could be increased."

[47] Liu et al. (2020, Emerging Infectious Diseases)

- On March 19, 2020, case-patient A0 returned to Heilongjiang Province from the United States; she was asked to quarantine at home. Patient B1.1 was the downstairs neighbour of case-patient A0. They used the **same elevator in the building** but not at the same time and did not have close contact otherwise.
- "We believe A0 was an asymptomatic carrier (7,8) and that B1.1 was infected by contact with surfaces in the elevator in the building where they both lived (9). Other residents in A0's building tested negative for SARS-CoV-2 nucleic acids and serum antibodies."
- Viral genome sequencing supported A0 as the origin of the cluster.

[48] Yuan et al. (2020, China CDC Weekly)

- Patient A is a **dockworker** who was infected after loading and unloading **imported frozen seafood** at Qingdao Port on September 19. After being diagnosed on September 24, he had been transferred to Qingdao Chest Hospital. 12 subsequent cases were identified in the same hospital.
- Big data screening and tracking showed that there was no temporal or spatial correlation between the patients and the close contacts in this outbreak and Patient A or his contacts before he was transferred to Qingdao Chest Hospital. A surveillance video confirmed that Patient A had been escorted from the isolation ward on the afternoon of September 24 to undergo a computerized tomography (CT) examination, possibly contaminating the CT examination room with virus due to lack of standardized disinfection.
- **Contamination of the CT room** most likely led to infections of Patients B and C, who had CT exams the following morning. They, in turn, likely brought the virus into the area for TB patients, and thus continued the spread of COVID-19.

- From October 11 to 15, Qingdao City CDC collected 129 environmental samples at Qingdao Chest Hospital, including from the CT room, tuberculosis patient wards, and sewage pipes. All samples had negative nucleic acid test results. Close contacts of all cases, close contacts of the close contacts, and all staff of Qingdao Chest Hospital and their visitors underwent a total of 5 nucleic acid tests each; all tests were negative.
- Authors conclude "This outbreak was **likely an in-hospital infection** caused by a lack of standardized disinfection of the hospital's CT room."

[49] Zhao et al. (2020, China CDC Weekly)

- From July 22–23, 3 local COVID-19 cases were reported in Dalian City, Liaoning Province, China. All 3 patients reported that they did not leave Dalian 14 days before the onset of disease and had no COVID-19 case contact history and no foreign personnel contact history. 12 asymptomatic infections were detected in close contacts of Patient 1.
- Genomic sequencing confirmed that this outbreak in Dalian may have been caused by the introduction of an infectious source as it was found to be different from the virus that was prevalent in Wuhan in December 2019.
- Cases of COVID-19 had not been reported in Dalian for more than 100 days before the first reemergent case occurred on June 22, 2020. Judging from the timing and phylogenetic analysis, the virus was likely imported from outside. According to the genomic epidemiological analysis, there was no clear relationship between the outbreak in Dalian and that in Beijing, and there was no evidence to suggest a definite link between the imported cases from other countries and Dalian.
- The authors conclude: "The Dalian outbreak was likely related to the processing of cold chain seafood products, especially imported contaminated products."

New observational environmental detection studies

[7] Marcenac et al. (2021, International Journal of Environmental Research and Public Health)

- Ten households with 1 or more persons with laboratory-confirmed COVID-19 and with 2 or more members total were enrolled in Utah, U.S.A.
- SARS-CoV-2 RNA was detected in 23 (15%) of 150 environmental swab samples, most frequently on **nightstands** (4/6; 67%), **pillows** (4/23; 17%), and **light switches** (3/21; 14%). **Viable SARS-CoV-2 was cultured from one sample**.
- All households with SARS-CoV-2-positive surfaces had 1 or more persons who first tested positive for SARS-CoV-2 <=6 days prior to environmental sampling.
- Viability was assessed through daily monitoring of cell cultures for virus-induced cytopathic effects (CPE). CPE-positive samples were confirmed for SARS-CoV-2 by RT-PCR.

Table 1. Location and cycle threshold (Ct) [a] value of SARS-CoV-2 detected at environmental surfaces sampled in each of ten households (HHs) with ≥1 laboratory-confirmed case of COVID-19.

Household ID	Number (% [b]) of Sampled Surfaces with Detectable SARS-CoV-2 RNA	HH Surfaces with Detectable SARS-CoV-2 RNA (C_t)
HH-01	2 (13)	Pillow of secondary HH case (36.4); phone (37.0)
HH-02	0 (0)	..
HH-03	0 (0)	..
HH-04	0 (0)	..
HH-05	0 (0)	..
HH-06	3 (20)	Light switch (37.2); pillow of index case (35.0); trash can lid (32.1)
HH-07	2 (13)	Nightstand of index case (34.1); computer (36.6)
HH-08	1 (7)	Pillow of other HH member (36.2)
HH-09	13 (87)	2 light switches (29.6, 33.4); refrigerator handle (29.3); nightstand of index case (26.4), nightstands of 2 secondary HH cases (33.8, 35.7); 2 doorknobs (29.8, 30.6); kitchen counter (33.2); microwave handle (31.8); kitchen sink handle (34.8); furniture (34.7); TV remote control (28.8)
HH-10	2 (13)	Pillow of index case (32.8); bathroom sink handle (34.8)

[a] Ct value is reported as the mean of Ct values from 2 SARS-CoV-2 genes (N1 and N2). High Ct values indicate there is less viral RNA, while low Ct values indicate more viral RNA. [b] Fifteen surfaces were sampled in each household.

- We used all 23 RT-PCR-positive environmental samples to inoculate Vero cells; **in one (4%) of 23 samples, we observed CPE and confirmed SARS-CoV-2 recovery.** This sample came from a nightstand swab (Ct = 26.4) belonging to an index case (Case ID 09-00, a 35-year-old man) with respiratory symptoms whose NP swab was positive for SARS-CoV-2 (Ct = 15.5) on the environmental sampling date. This man first tested positive for SARSCoV- 2 two days prior to environmental sampling and lived in a household with a 100% secondary attack rate.
- Of the three households with detectable SARS-CoV-2 RNA in the environment but no secondary transmission, two (67%) reported taking isolation measures and two (67%) reported using disinfecting wipes and sprays on high-touch surfaces. We found no cases of secondary transmission in the four households that did not have detectable SARS-CoV-2 RNA in the environment. These four households reported that infected persons isolated themselves from other household members using 1 of the following strategies: sleeping in separate bedrooms (4/4, 100%), using separate bathrooms (4/4, 100%), or eating separately from household members (3/4, 75%). Two (50%) of these four households reported using disinfecting wipes and sprays on high-touch surfaces after someone became ill with COVID-19.
- Authors conclude: "SARS-CoV-2 surface contamination occurred early in the course of infection when respiratory transmission is most likely, notably on surfaces in close, prolonged contact with persons with COVID-19. **While fomite transmission might be possible, risk is low**."
- "To our knowledge, this is the first recorded instance of viable SARS-CoV-2 recovery from an environmental swab in a real-life, non-laboratory setting."

[50] Elbadawy et al. (2021, Journal of Medical Virology)

- RT-PCR was used to detect the presence of SARS-CoV-2 on swabs taken from the hands of patients and from surfaces and objects.
- In the COVID-19 regional reference hospital, only 3 out of 20 samples were positive for SARS-CoV-2 RNA. Hand swabs from SARS-CoV-2-positive patients in isolation rooms were occasionally positive for viral RNA. In outpatients' clinics, door handles were the most contaminated surfaces. Dental chairs, sinks, keyboards, ophthalmoscopes, and laboratory equipment were also contaminated. Although no positive swabs were found in shops and public facilities, random ATM swabs returned a positive result for SARS-CoV-2 RNA.

[51] Liu, Li et al. (2021, Environmental Microbiology)

- Collected 431 environmental (391 surface and 40 air) samples in the intensive care unit (ICU) and general wards (GWs) of three hospitals in Wuhan, China from February 21 to March 4, 2020, and detected SARS-CoV-2 RNA by real-time quantitative PCR. The viral positive rate in the contaminated areas was 17.8% (28/157) whereas there was no virus detected in the clean areas.
- No virus culture was utilized to confirm the viral activity.

[52] Huang et al. (2021, Journal of Microbiology, Immunology and Infection)

- Investigated a superspreading event of COVID-19 in a hospital and explored the transmission dynamics.
- Surface samples taken in the room showed environmental contamination by the patient, suggesting probable fomite transmission, in addition to the transmission via respiratory droplets.
- 20 samples collected from the room that patient 1 stayed in the ward 5C. SARS-CoV-2 RNA was found in four samples.

[53] Rocha et al. (2021, Scientific Reports)

- Aims were: (i) to investigate the presence of SARS-CoV-2 in inanimate objects using RT-qPCR and (ii) to investigate the presence of SARS-CoV-2 in the air and in the sewage using RT-qPCR.
- Collected samples of mask fronts, cell phones, paper money, card machines, sewage, air and bedding. Samples were kept refrigerated at 4–8 °C and analyzed up to 6 h after being collected. The study was conducted during the ascendant phase of the epidemiological curve of COVID-19 in Barreiras city.
- Sampling was carried out from June 1, 2020 to May 13, 2021. Four of these samplings were carried out at the main market area of Barreiras (an open public place with intense circulation of people).
- Detected the human RNAse P gene in most of samples, which indicates the presence of human cells or their fragments in specimens. However, did not detect any trace of SARS-CoV-2 in all samples analyzed.

[54] Faezeh seif et al. (2021, Environmental Research)

- Detection of SARS-CoV-2 RNA was performed using 76 samples from environmental surfaces that were obtained from different hospital wards before disinfection and cleaning, from which 40 samples were positive

[55] Liu, Fei, et al. (2021, Environmental Research)

- Investigated SARS-CoV-2 RNA existence in room-temperature and low-temperature environments long after exposure (>28 days).
- A department store, and a patient's apartment were included as room-temperature environments after being blocked for 57 days and 48 days, respectively. Seven cold storages and imported frozen foods inside were included as low-temperature environments (under ~18 ◦C). Twenty food markets with potential contamination of imported frozen foods were also included to study the consecutive contamination.
- After RT-PCR testing, 35 (0.30 %) swab samples were positive. In sum, 11,808 swab samples were collected before disinfection. Persistent contamination of SARS-CoV-2 RNA was identified in the apartment (6/19), the department store (3/50), food packages in cold storages (23/1360), environmental surfaces of cold storages (2/345), and a package in the food market (1/10,034).

[56] Li, Fan, et al. (2020, Epidemiology and Infection)

- Examined the concentration of SARS-CoV-2 in aerosol samples and on environmental surfaces in a hospital designated for treating severe COVID-19 patients. Aerosol samples were collected by a microbial air sampler, and environmental surfaces were sampled using sterile premoistened swabs at multiple sites. Ninety surface swabs and 135 aerosol samples were collected. Only two swabs, sampled from the inside of a patient's mask, were positive for SARS-CoV-2 RNA. All other swabs and aerosol samples were negative for the virus.

[57] Nissen et al. (2020, Scientific Reports)

- Although RNA could be detected in samples from ward rooms and central ventilation ducts, no infectivity was seen after inoculating samples on susceptible cells.

Expert summaries

[58] CDC Science Brief: SARS-CoV-2 and Surface (Fomite) Transmission for Indoor Community Environments (5 April 2021

- The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory droplets carrying infectious virus. It is **possible** for people to be infected through contact with contaminated surfaces or objects (fomites), but t**he risk is generally considered to be low**.
- The risk of fomite-mediated transmission is dependent on:
    - The infection prevalence rate in the community
    - The amount of virus infected people expel (which can be substantially reduced by wearing masks)
    - The deposition of expelled virus particles onto surfaces (fomites), which is detected by air flow and ventilation
    - The interaction with environmental factors (e.g., heat and evaporation) causing damage to virus particles while airborne and on fomites
    - The time between when a surface becomes contaminated and when a person touches the surface
    - The efficiency of transference of virus particles from fomite surfaces to hands and from hands to mucous membranes on the face (nose, mouth, eyes)
    - The dose of virus needed to cause infection through the mucous membrane route
- It is not clear what proportion of SARS-CoV-2 infections are acquired through surface transmission.
    - Case reports indicate that SARS-CoV-2 is transmitted between people by touching surfaces an ill person has recently coughed or sneezed on, and then directly touching the mouth, nose, or eyes.
    - Quantitative microbial risk assessment (QMRA) studies suggest that **the risk of SARS-CoV-2**

infection via the fomite transmission route is low, and generally less than 1 in 10,000, which means that each contact with a contaminated surface has less than a 1 in 10,000 chance of causing an infection
    - **Surface survival**: On porous surfaces, studies report inability to detect viable virus within minutes to hours; on non-porous surfaces, viable virus can be detected for days to weeks. When accounting for both surface survival data and real-world transmission factors, **the risk of fomite transmission after a person with COVID-19 has been in an indoor space is minor after 3 days (72 hours), regardless of when it was last cleaned.**
- Both cleaning (use of soap or detergent) and disinfection (use of a product or process designed to inactivate SARS-CoV-2) can reduce the risk of fomite transmission.

[59] The National Collaborating Centre for Methods and Tools (5 March 2021) Rapid Review Update 1: What is known about how long the virus can survive with potential for infection on surfaces found in community settings?

- Includes evidence available up to 31 December 2020, which comprises of 7 completed syntheses, 2 in progress syntheses and 32 single studies.
- Key points:
    - There is consistent evidence that fragments of SARS-CoV-2 can be detected on surfaces in community settings for up to seven days, the certainty of evidence is considered moderate. However, most of these studies measure viral genetic material, so did not distinguish between live virus and dead virus or viral fragments. Only one study measured viable virus (that which has potential to infect) in samples and found none to be present.
    - Overall, viral fragments can be detected on surfaces, but these fragments may not be viable, with the certainty of evidence considered low.
    - Of the studies that reported whether cleaning of surfaces had occurred prior to sampling, disinfecting / cleaning procedures consistently decreased or eliminated detection of SARS-CoV-2 fragments. The certainty of the evidence is considered moderate.
    - Findings from laboratory-based studies indicate SARS-CoV-2 can remain viable longer on smoother surfaces such as plastic or steel than cardboard or cotton. However often with starting concentrations much higher than found in the environment. There is wide variation in the length of times reported but there is indication of increased stability at lower temperatures (such as 4°C) and more rapid decay with increasing temperatures.
    - Only one prevalence study, by Döhla et al. attempted to detect viable virus (live virus that has retained potential to infect) by viral culture test, and did not detect any, despite finding positive samples by real-time RT-PCR (suggesting these positive samples may not have been viable virus). Therefore, there appears to be low risk of infection from touching a contaminated surface, although the evidence is very limited due to only one study using a viral culture test for live virus.

[60] National Collaborating Centre for Environmental Health (23 March 2021) Fomites and the COVID-19 pandemic: An evidence review on its role in viral transmission

- Although limited, current evidence indicates that the **risk of infection from fomites is low**, and fomites are not likely to be the major transmission pathway for SARS-CoV-2 in most situations. However, SARS-CoV-2 RNA has been found on environmental surfaces in hospital rooms, quarantine rooms, and other community settings, implying that the surfaces can become contaminated with SARS-CoV-2 despite few studies being able to culture live viruses.
- Reported on **5 case studies** (3 reported in previous briefing, 2 new but transmission route was attributed to either fomites and respiratory, noted in the case study section). The author concludes that the **evidence is mostly circumstantial and not definitive**. Many of the clusters/outbreaks may have been transmitted through multiple pathways.

Authors: Prof Caroline Miller, Dr Jo Dono, Prof Steve Wesselingh
Searcher: Nikki May (SALHN Reference Librarian)

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