RESEARCH LETTER

Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient

Coronaviruses have been implicated in nosocomial outbreaks[1] with environmental contamination as a route of transmission.[2] Similarly, nosocomial transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been reported.[3] However, the mode of transmission and extent of environmental contamination are unknown.

Methods | From January 24 to February 4, 2020, 3 patients at the dedicated SARS-CoV-2 outbreak center in Singapore in airborne infection isolation rooms (12 air exchanges per hour) with anterooms and bathrooms had surface environmental samples taken at 26 sites. Personal protective equipment (PPE) samples from study physicians exiting the patient rooms also were collected. Sterile premoistened swabs were used.

Author Audio Interview

Audio and Supplemental content

Air sampling was done on 2 days using SKC Universal pumps (with 37-mm filter cassettes and 0.3-µm polytetrafluoroethylene filters for 4 hours at 5 L/min) in the room and anteroom and a Sartorius MD8 microbiological sampler (with gelatin membrane filter for 15 minutes at 6 m^3/h) outside the room (eFigure in the Supplement).

Specific real-time reverse transcriptase–polymerase chain reaction (RT-PCR) targeting RNA-dependent RNA polymerase and E genes[4] was used to detect the presence of SARS-CoV-2 (see detailed methods in the eAppendix in the Supplement). Cycle threshold values, ie, number of cycles required for the fluorescent signal to cross the threshold in RT-PCR, quantified viral load, with lower values indicating higher viral load.

Samples were collected on 5 days over a 2-week period. One patient's room was sampled before routine cleaning and 2 patients' rooms after routine cleaning. Twice-daily cleaning of high-touch areas was done using 5000 ppm of sodium dichloroisocyanurate. The floor was cleaned daily using 1000 ppm of sodium dichloroisocyanurate.

Clinical data (symptoms, day of illness, and RT-PCR results) and timing of cleaning were collected and correlated with sampling results. Percentage positivity was calculated for rooms with positive environmental swabs. Institutional review board approval and written informed consent were obtained as part of a larger multicenter study.

Results | Patient A's room was sampled on days 4 and 10 of illness while the patient was still symptomatic, after routine cleaning. All samples were negative. Patient B was symptomatic on day 8 and asymptomatic on day 11 of illness; samples taken on these 2 days after routine cleaning were negative (**Table 1**).

Patient C, whose samples were collected before routine cleaning, had positive results, with 13 (87%) of 15 room sites (including air outlet fans) and 3 (60%) of 5 toilet sites (toilet bowl, sink, and door handle) returning positive results (**Table 2**). Anteroom and corridor samples were negative. Patient C had upper respiratory tract involvement with no pneumonia and had 2 positive stool samples for SARS-CoV-2 on RT-PCR despite not having diarrhea.

Patient C had greater viral shedding, with a cycle threshold value of 25.69 in nasopharyngeal samples compared with 31.31 and 35.33 in patients A and B (Table 1).

Only 1 PPE swab, from the surface of a shoe front, was positive. All other PPE swabs were negative. All air samples were negative.

Discussion | There was extensive environmental contamination by 1 SARS-CoV-2 patient with mild upper respiratory tract involvement. Toilet bowl and sink samples were positive, suggesting that viral shedding in stool[5] could be a potential route of transmission. Postcleaning samples were negative, suggesting that current decontamination measures are sufficient.

Table 1. Sampling Time Points in Relation to Patient Illness and Clinical Cycle Threshold Values

Patient	Days of illness when samples were collected	Presence of symptoms during sampling	Symptoms	Disease severity[a]	Before/after routine cleaning	Cycle threshold value from clinical samples[b]
A	4, 10	Yes, both days	Cough, fever, shortness of breath	Moderate	After	31.31 (day 3); 35.33 (day 9)
B	8, 11	Yes on day 8; asymptomatic on day 11	Cough, fever, sputum production	Moderate	After	32.22 (day 8); not detected (day 11)
C	5	Yes	Cough	Mild	Before	25.69 (day 4)

[a] Disease severity was considered moderate if there was lung involvement (opacities on chest radiograph) and severe if patient required supplemental oxygen therapy.

[b] Clinical samples were either nasopharyngeal swabs or sputum samples if patient could produce sputum. The most recent result prior to the environmental sampling was recorded. Cycle threshold refers to the number of cycles required for the fluorescent signal to cross the threshold in reverse transcriptase–polymerase chain reaction; a lower cycle threshold value indicates a higher viral load.

Table 2. Environmental and PPE Sites Sampled and Corresponding RT-PCR Results

Sites[a]	Positive samples (patient C; before routine cleaning)[b]	Cycle threshold value[c]
Environmental sites[d]		
Patient's room		
1. Cardiac table, including handle	1/1	35.44
2. Entire length of bed rail	1/1	37.95
3. Control panel on bed	0/1	
4. Call bell attached to bed	0/1	
5. Locker with hand slot	1/1	36.21
6. Chair	1/1	37.07
7. Light switches behind bed	1/1	37.54
8. Stethoscope	1/1	38.24
9. Sink, external rim	1/1	35.54
10. Sink, internal bowl	1/1	36.79
11. Floor	1/1	30.64
12. Glass window in room	1/1	35.79
13. Glass door interior	1/1	35.71
14. PPE storage area over sink	1/1	34.89
15. Air outlet fan	2/3	32.96, 37.94
Toilet area		
16. Door handle	1/1	35.83
17. Toilet bowl, surface	1/1	37.75
18. Hand rail	0/1	
19. Sink, external rim	0/1	
20. Sink, internal bowl	1/1	37.11
Anteroom		
21. Sink, external rim	0/1	
22. Sink, internal bowl	0/1	
23. Floor	0/1	
24. Glass door, room side	0/1	
25. Glass door, corridor side	0/1	
Corridor outside room		
26. Floor	0/1	
Total, No. (%)	17/28 (61)	
Staff PPE sites		
Upper front part of gown	0/2	
Lower front part of gown	0/2	
Front surface of face visor mask	0/2	
Front surface of N95 mask	0/2	
Surface of front of shoes	1/2	38.96

Abbreviations: RT-PCR, reverse transcriptase–polymerase chain reaction; PPE, personal protective equipment.

[a] Numbering of environmental sites corresponds to the numbering in the eFigure in the Supplement.

[b] Results are shown as number of positive samples/number of total samples. All samples taken from patients A and B after routine cleaning were negative and not included in this table.

[c] Cycle threshold refers to the number of cycles required for the fluorescent signal to cross the threshold in RT-PCR; a lower cycle threshold value indicates a higher viral load.

[d] One swab was taken from each site except the air outlet fan, from which 3 swabs were taken.

Air samples were negative despite the extent of environmental contamination. Swabs taken from the air exhaust outlets tested positive, suggesting that small virus-laden droplets may be displaced by airflows and deposited on equipment such as vents. The positive PPE sample was unsurprising because shoe covers are not part of PPE recommendations. The risk of transmission from contaminated footwear is likely low, as evidenced by negative results in the anteroom and clean corridor.

This study has several limitations. First, viral culture was not done to demonstrate viability. Second, due to operational limitations during an outbreak, methodology was inconsistent and sample size was small. Third, the volume of air sampled represents only a small fraction of total volume, and air exchanges in the room would have diluted the presence of SARS-CoV-2 in the air. Further studies are required to confirm these preliminary results.

Significant environmental contamination by patients with SARS-CoV-2 through respiratory droplets and fecal shedding suggests the environment as a potential medium of transmission and supports the need for strict adherence to environmental and hand hygiene.

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Characteristics and Outcomes of 21 Critically Ill Patients With COVID-19 in Washington State

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the disease it causes, coronavirus disease 2019 (COVID-19), is an emerging health threat.[1] Until February 2020, most cases were described in non-US health systems.[2,3] One of the first deaths in the US was reported at Evergreen Hospital in Kirkland, Washington. Over the following weeks, multiple cases of COVID-19 were identified in the surrounding community and treated at Evergreen Hospital. Most were attributed to US transmission, and the majority were linked to exposures at a skilled nursing facility.

Viewpoint page 1545

Audio

In this case series, we describe the clinical presentation, characteristics, and outcomes of incident cases of COVID-19 admitted to the intensive care unit (ICU) at Evergreen Hospital to inform other clinicians treating critically ill patients with COVID-19.

Methods | Patients with confirmed SARS-CoV-2 infection (positive result by polymerase chain reaction testing of a nasopharyngeal sample) admitted to the ICU at Evergreen Hospital between February 20, 2020, and March 5, 2020, were included. Evergreen Hospital is a 318-bed public hospital with a 20-bed ICU serving approximately 850 000 residents of King and Snohomish counties in Washington State.

Prior to data collection, a waiver was obtained from the Evergreen Healthcare institutional review board. Deidentified patient data were collected and analyzed using Stata version 15.1 (StataCorp). Laboratory testing was reviewed at ICU admission and on day 5. Chest radiographs were reviewed by an intensivist and a radiologist. Patient outcome data were evaluated after 5 or more days of ICU care or at the time of death. No analysis for statistical significance was performed given the descriptive nature of the study.

Table 1. Baseline Characteristics of 21 Patients With Coronavirus Disease 2019 at Presentation to the Intensive Care Unit

Baseline characteristics	No. (%) of patients[a]	Reference range
Preadmission comorbidities		
Asthma	2 (9.1)	
Chronic obstructive pulmonary disease	7 (33.3)	
Congestive heart failure	9 (42.9)	
Diabetes	7 (33.3)	
Rheumatologic disease	1 (4.8)	
Obstructive sleep apnea	6 (28.6)	
Chronic kidney disease	10 (47.6)	
End-stage kidney disease	2 (9.5)	
History of solid organ transplant	2 (9.5)	
Cirrhosis	1 (4.8)	
Immunosuppression[b]	3 (14.3)	
Total with ≥1 comorbidity	18 (85.7)	
Admission symptoms		
Cough	11 (47.6)	
Shortness of breath	17 (76.2)	
Fever[c]	11 (52.4)	
Temperature (range), °C	37.6 (35.3-39.2)	
Admission chest radiograph findings[d]		
Bilateral reticular nodular opacities	11 (52.4)	
Ground-glass opacities	10 (47.6)	
Pleural effusion	6 (28.6)	
Peribronchial thickening	5 (23.8)	
Pleural effusion	5 (23.8)	
Focal consolidation	4 (19.0)	
Pulmonary edema	2 (9.5)	
Venous congestion	1 (4.8)	
Atelectasis	1 (4.8)	
Clear	1 (4.8)	
Admission laboratory measures, mean (range)[a]		
White blood cell count, /μL	9365 (2890-16 900)	4000-11 000
Absolute lymphocyte count, /μL	889 (200-2390)	1000-3400
Hemoglobin, g/dL	11.4 (8.0-13.7)	11.2-15.7
Platelet count, $\times 10^3$/μL	215 (52-395)	182-369
Sodium, mmol/L	137 (125-148)	135-145
Creatinine, mg/dL	1.45 (0.1-4.5)	0.6-1.2
Total bilirubin, mg/dL	0.6 (0.2-1.1)	0-1.5
Alkaline phosphatase, U/L	80 (41-164)	31-120
Aspartate aminotransferase, U/L[e]	273 (14-4432)	5-40
Alanine aminotransferase, U/L[e]	108 (11-1414)	5-50
Creatinine kinase, U/L	95 (45-1290)	21-215
Venous lactate, mmol/L	1.8 (0.8-4.9)	<1.9
Had troponin level >0.3 ng/mL, No. (%)	3 (14.0)	
Brain-type natriuretic peptide, pg/mL	4720 (69-33 423)	<450
Procalcitonin, ng/mL	1.8 (0.12-9.56)	0.15-2.0
Underwent bronchoalveolar lavage, No. (%)	7 (33.0)	

(continued)

Results | A total of 21 cases were included (mean age, 70 years [range, 43-92 years]; 52% male). Comorbidities were identified in 18 cases (86%), with chronic kidney disease and congestive heart failure being the most common. Initial symptoms included shortness of breath (76%), fever (52%), and cough (48%) (**Table 1**). The mean onset of symptoms prior to presenting to the hospital was 3.5 days, and 17 patients (81%) were admitted to the ICU less than 24 hours after hospital admission.