Detection of Air and Surface Contamination by SARS-CoV-2 in Hospital Rooms of Infected Patients

Caleb Goh, Daphne Chu, Seet Ming Kang, Chan Yong Hoe

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Introduction

SARS-CoV-2 is the causative virus of COVID-19, which has spread globally, with ongoing local transmissions in many countries despite control efforts. Understanding the different transmission routes of SARS- CoV-2 is crucial in planning effective interventions to break the chain of transmission.

Objective

Identify the degree of environmental contamination by SARS-CoV-2 in hospitalised COVID-19 patients at different stages of illness

Hypothesis

SARS-CoV-2 is shed in the air and on high touch surfaces by COVID-19 patients, enabling transmission via airborne and fomite routes.

Methodology

Study design

- Location: Airborne Infection Isolation Rooms (AIIRs) in National Centre for Infectious Diseases (NCID), Singapore
- Characteristics of AIIRs: 12 air changes/h, average temperature 23 °C, relative humidity 53–59%, exhaust flow 579.6 m3/h

Selection of patients

Patients with a SARS-CoV-2 infection confirmed by a positive polymerase chain reaction (PCR) respiratory sample within the prior 72h

Data collected from patients

Clinical characteristics, including the presence of symptoms, day of illness, day of stay in the room, supplemental oxygen requirement, and baseline characteristics

Cleaning regimen of the rooms

Routine environmental cleaning of the rooms was carried out by a trained team of housekeeping staff

1. Sampling of surfaces and air → **2. Laboratory methods** → **3. Statistical analysis**

1. Sampling

Sampling of Surfaces

- Surface samples were collected with Puritan EnviroMax Plus pre-moistened macrofoam sterile swabs (25-88060)
- 8 to 20 surface samples were collected from each room
- Five surfaces were designated high-touch surfaces, including the cardiac table, entire length of the bed rails including bed control panel and call bell, bedside locker, electrical switches on top of the beds, and chair in general ward rooms (Fig. 1)
- In ICU rooms, the ventilator and infusion pumps were sampled instead of the electrical switches on top of the beds and chair (Fig. 2)
- All surfaces sampled are listed in Table 1

Sampling of Air

- Six NIOSH BC 251 bioaerosol samplers were placed in each of three AIIRs in the general ward to collect air samples (Fig. 1)
- Particles are separated into 3 sizes based on their diameter: >4μm, 1-4μm, <1μm
- The six NIOSH samples from each room were pooled prior to analysis, but the particle size fractions remained separated. Each sample pool was representative of 5040L air

Table 1: All sites sampled, and the number of rooms sampled per site

Environmental Site	No. of rooms sampled
Patient room	
Cardiac table	30
Bed rail (including control panel and call bell)	30
Bedside locker	30
Floor	30
Chair	27
Switches over top of beds	27
Air exhaust outlet vent	5
Glass window in the room	5
Ventilator (ICU)	3
Infusion pumps (ICU)	3
Surgical pendants (ICU)	3
Vital sign display screen (ICU)	3
Stethoscope	3
Sink, external surface	3
Sink, internal bowl	3
Interior of room glass door	3
PPE storage area over sink	2
Toilet	
Toilet seat & automatic flush button	27
Door handle	2
Hand rail	2
Sink, external surface	2
Sink, internal bowl	2

2. Laboratory methods

- The QIAamp viral RNA mini kit (Qiagen Hilden, Germany) was used for sample RNA extraction
- Real-time PCR assays targeting the envelope (E) genes (1) and an orf1ab assay modified from Drosten et al. (2) were used to detect SARS-CoV-2 in the samples
- Positive detection was recorded as long as amplification was observed in at least one assay

3. Statistical analysis

- Statistical analysis was performed using Stata version 15.1 (StataCorp, College Station, Texas) and GraphPad Prism 8.0 (GraphPad Software, Inc., San Diego)
- For the surface environment, outcome measures analyzed were any positivity by room and pooled percentage positivity by day of illness and respiratory viral load (represented by clinical cycle threshold (Ct) value in Fig. 3)

Fig.1 : Cycle threshold values of both clinical samples and environmental samples against the day of illness

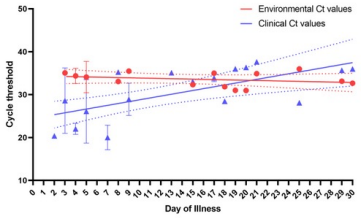
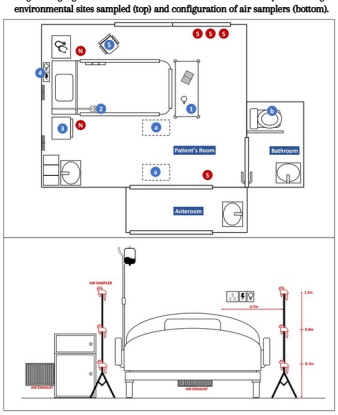
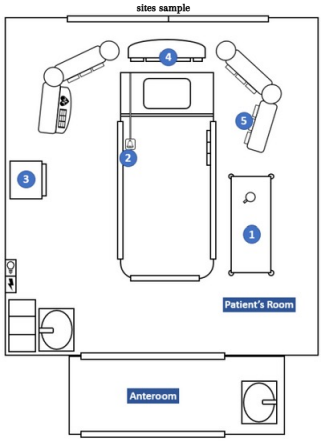


Fig. 2: Single general ward airborne infection isolation room layout showing environmental sites sampled (top) and configuration of air samplers (bottom).



Top: Blue circles mark 5 high-touch areas: (1) cardiac table, (2) bed rail (including call bell), (3) locker, (4) switches, and (5) chair; as well as other key sites sampled: (a) floor, (b) toilet bowl seat. Red circles labelled "N" mark out positions of NIOSH air samplers, while red circles labelled "S" mark out positions of SKC air samplers (only in room 1). During the air sampling duration, patient 1 was seated in the chair while patients 2 and 3 were lying in bed. Bottom: Configuration of air samplers depicts air sampling layout in rooms 2 and 3 only

Fig. 3: Single intensive care unit room layout showing environmental sites sample



Blue circles mark 5 high-touch areas: (1) cardiac table, (2) bed rail (including call bell), (3) locker, (4) ventilator, and (5) surgical pendants.

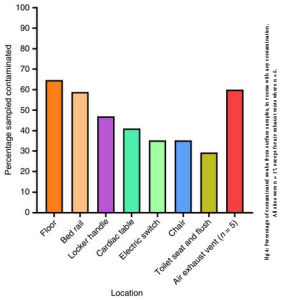
Results

Air sample testing

- Air samples from two (66.7%) of three AIIRs tested positive for SARS-CoV-2, in particle sizes >4 μm and 1-4 μm in diameter
- Air samples from the fractionated size <1 μm were all negative, as were all non-size-fractionated samples

Viral load detected

- Total SARS-CoV-2 concentrations in air ranged from 1.84 × 103 to 3.38 × 103 RNA copies per m3
- Median cycle threshold (Ct) values of the clinical specimens for patients with and without environmental surface contamination were 25.69 (IQR 20.37–34.48) and 33.04 (28.45–35.66) respectively



Viral surface contamination

- Rooms with viral particles detected in the air also had surface contamination detected
- The floor was most likely to be contaminated (65%), followed by the air exhaust vent (60%, n = 5), bed rail (59%), and bedside locker (47%) (Fig. 4).
- Contamination of toilet seat and automatic toilet flush button was detected in 5 out of 27 rooms, with all patients reporting gastrointestinal symptoms within the preceding week of sampling

Factors associated with degree of viral contamination

- Presence and concentration of SARS-CoV-2 in air and high-touch surface samples:
  1. Correlated with day of illness (highest in 1st week) and nasopharyngeal viral loads of patients
  2. Showed association with the clinical cyclical threshold
- Surface environment contamination was not associated with the presence of symptoms

Discussion and Conclusion

Conclusion

- SARS- CoV-2 can be shed in the air in particles sized between 1 and 4 microns
- Surface viral contamination is attributable to both direct touch and respiratory droplets
- These point towards the potential for airborne and fomite transmission of SARS-CoV2

Limitations

- Factors affecting the production of viable viruses:
  - Potential stress to viruses during sampling
  - Questionable ability to culture viruses
- AIIR environment is non-representative of community settings
- Timing of sampling: samples were obtained at a single time point during the course of illness
- Extended period of time (72h) between collection of clinical results and environmental sampling - viral load and hence degree of environmental contamination may be affected
- Tedious process involved in gaining approval and permission from authorities

Future Work

- Improve sampling methods and using enhanced virus culture techniques (3)
- Sample a greater volume of patients
- Sample patients in the community setting
- Consider other factors that can affect the amount of viral particles shed/degree of contamination

References

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