Detection of COVID-19 Outbreaks in Long-Term Care Homes Using Built Environment Testing for SARS-CoV-2: A Multicentre Prospective Study

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Abstract

Background. Environmental surveillance of SARS-CoV-2 via wastewater has become an invaluable tool for population-level surveillance of COVID-19. Built environment sampling may provide a more spatially refined approach for surveillance of COVID-19 in congregate living settings and other high risk settings (e.g., schools, daycares). **Methods**. We conducted a prospective study in 10 long-term care homes (LTCHs) across three cities in Ontario, Canada between September 2021 and May 2022. Floor surfaces were sampled weekly at multiple locations (range 10 to 24 swabs per building) within each building and analyzed for the presence of SARS-CoV-2 using RT-qPCR. The exposure variable was detection of SARS-CoV-2 on floors. The primary outcome was the presence of a COVID-19 outbreak in the week that floor sampling was performed. Over the 9-month study period, we collected 3848 swabs at 10 long-term care homes. **Results**. During the study period, 19 COVID-19 outbreaks occurred with 103 cumulative weeks under outbreak. During outbreak periods, the proportion of floor swabs positive for SARS-CoV-2 was 50% (95% CI: 47-53) with a median quantification cycle of 37.3 (IQR 35.2-38.7). During non-outbreak periods the proportion of floor swabs positive was 18% (95% CI:17-20) with a median quantification cycle of 38.0 (IQR 36.4-39.1). Using the proportion of positive floor swabs for SARS-CoV-2 to predict COVID-19 outbreak status in a given week, the area under the receiver operating curve (AUROC) was 0.85 (95% CI: 0.78-0.92). Using thresholds of ≥10%, ≥30%, and ≥50% of floor swabs positive for SARS-CoV-2 yielded positive predictive values for outbreak of 0.57 (0.49-0.66), 0.73 (0.63-0.81), and 0.73 (0.6-0.83) respectively and negative predictive values of 0.94 (0.87-0.97), 0.85 (0.78-0.9), and 0.75 (0.68-0.81) respectively. Among 8 LTCHs with an outbreak and swabs performed in the antecedent week, 5 had positive floor swabs exceeding 10% at least five days prior to outbreak identification. For 3 of these 5 LTCHs, positivity of floor swabs exceeded 10% more than 10 days before the outbreak being identified. **Conclusions**. Detection of SARS-CoV-2 on floors is strongly associated with COVID-19 outbreaks in LTCHs. These data suggest a potential role for floor sampling in improving early outbreak identification.

Objectives

1. **To determine the test characteristics of built environment screening for the identification of long-term care home COVID-19 outbreaks.**
2. **To evaluate whether outbreaks in long-term care homes could be identified earlier using built environment screening.**

Methods

We conducted a multicentre prospective study of built environment swabbing for SARS-CoV-2 in a sample of 10 LTCHs in Ontario, Canada, between September 2021 and May 2022. At each LTCH, we had a site visit with the LTCH manager and their infection control team to identify swab locations. The swab locations included common areas shared by both residents and staff (e.g., dining areas, recreation rooms, hallways) and staff-only areas (e.g., staff locker rooms, staff lunch rooms, kitchen, laundry areas). Swab samples were taken from the same locations weekly. Between 10-20 swabs were performed each week at each LTCH depending on the size of the building. Sample collection followed previously validated protocols, and involved initial swab wetting in nucleic acid stabilization solution followed by approximately 30 seconds of swabbing across a 2"x 2" area. Floors were sampled using the P-208 Environmental Surface Collection Prototype kit from DNA Genotek. The swabs were then sent to our lab and SARS-CoV-2 was detected by quantitative reverse-transcriptase polymerase chain reaction (RT-qPCR) of RNA extracted from the stabilization solution using the MagMAX Viral/Pathogen II (MVP II) Nucleic Acid Isolation Kit (Thermo Fisher Scientific, Waltham, MA). The RT-qPCR results provided a quantification cycle (Cq) of detection for each positive swab. For our study we considered a positive result to be a Cq value less than 45, consistent with cut-offs used for wastewater surveillance and other qPCR applications. COVID-19 outbreak and weekly case count data were reported to us by the LTCH managers and cross-checked with public health records. The primary outcome was the presence of a COVID-19 outbreak in a LTCH during a given week. Our study was reviewed by the research ethics board at the University of Ottawa and received a waiver of consent. Descriptive statistics are reported. We determined the test characteristics of the proportion of PCR-positive swabs for predicting an outbreak in a given facility for a given week. The sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV), of the proportion of PCR-positive swabs were estimated for various decision thresholds.

Results

Over a 9-month time period we serially swabbed 10 LTCHs. Summary statistics for all covariates are given in Table 1. All sites had vaccination rates exceeding 95% for both staff and residents. Among the LTCHs, most buildings (70%) were built prior to 1980, 2 had primarily single occupancy rooms, and there were an average of 155 residents per LTCH and 213 staff per LTCH. A total of 3,848 swabs were collected (mean 385 per home), 2,024 CO2 measurements were recorded (50% of LTCHs), and 19 COVID-19 outbreaks were declared.

Table 1. Baseline characteristics of the included long-term care homes.

N homes	10
Buildings	
Year built	1974 (1966, 2004)
Number of floors	3 (1, 7)
Total rooms	125 (58, 533)
Total residence rooms	112 (35, 374)
% single occupancy	29.6 (5.3, 100)
Resident level	
Number of residents	149.5 (63, 300)
Percentage vaccinated	98.15 (92.8, 100)
Staff level	
Number of staff	200.5 (93, 383)
Percentage vaccinated	100 (95, 100)

Expressed as *median (min, max)*

Table 2. Detection of SARS-CoV-2 and CO2 readings stratified by outbreak status.

	Overall	Outbreak	Staff cases	No cases
Percentage of PCR-positive swabs				
All locations	28.9 (27.5-30.4)	50.1 (47.4-52.8)	12.8 (9.4-17.1)	18.9 (17.3-20.6)
Shared areas*	28.6% (26.8-30.4)	48.9% (45.5-52.2)	8.7% (5.7-13)	19.9% (17.8-22)
Worker-only areas	29.5% (27.1-32)	52.3% (47.7-56.8)	28.8% (18.8-41.4)	17.2% (14.7-19.9)
Cycle threshold of positive swabs				
Cycle threshold	37.7 (35.6-38.9)	37.3 (35.2-38.7)	38 (36.4-38.7)	38 (36.3-39.1)
Covariates				
Carbon-dioxide (ppm)	522 (458-597)	523 (473-586)	424 (376-499)	536 (471-612)

PCR-positive swabs expressed as percentage with 95% CI by Wilson method
Cycle-threshold and CO_2 expressed as median (IQR)
* refers to areas in the long-term care home where the space is shared by both residents and workers

Table 3. Percentage of swabs positive for SARS-CoV-2 in the days leading up to the identification of an outbreak and after the end of an outbreak.

	Days before outbreak			Days after outbreak	
	15:21	8:14	1:7	+1:7	+8:14
n Swabs	265	238	279	161	183
% Positive	23% (19-29)	34% (28-40)	42% (37-48)	48% (40-56)	36% (29-43)
Cycle threshold	37.6 (35.8-38.8)	38.7 (36.6-39.5)	37.5 (34.9-38.7)	37.7 (36.4-39.3)	38.4 (36.5-39.2)

% positive swabs expressed as *percentage* (95% CI).
CIs computed by Wilson's method for binomial proportions.
PCR cycle threshold values expressed as *median* (IQR).

Table 4. Test characteristics of floor swabs to identify a current outbreak.

Threshold	Sensitivity	Specificity	NPV	PPV
10%	0.93 (0.85-0.97)	0.6 (0.52-0.68)	0.94 (0.87-0.97)	0.57 (0.49-0.66)
20%	0.84 (0.75-0.91)	0.72 (0.64-0.79)	0.89 (0.82-0.93)	0.64 (0.54-0.72)
30%	0.75 (0.64-0.83)	0.84 (0.77-0.89)	0.85 (0.78-0.9)	0.73 (0.63-0.81)
40%	0.6 (0.49-0.7)	0.86 (0.8-0.91)	0.79 (0.72-0.85)	0.71 (0.6-0.81)
50%	0.49 (0.39-0.6)	0.9 (0.84-0.94)	0.75 (0.68-0.81)	0.73 (0.6-0.83)

Test characteristics expressed as estimate (95% CI by Wilson

Figure 2. Test characteristics across swab positivity ranging from 0% to 100%

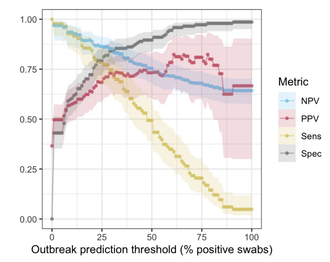
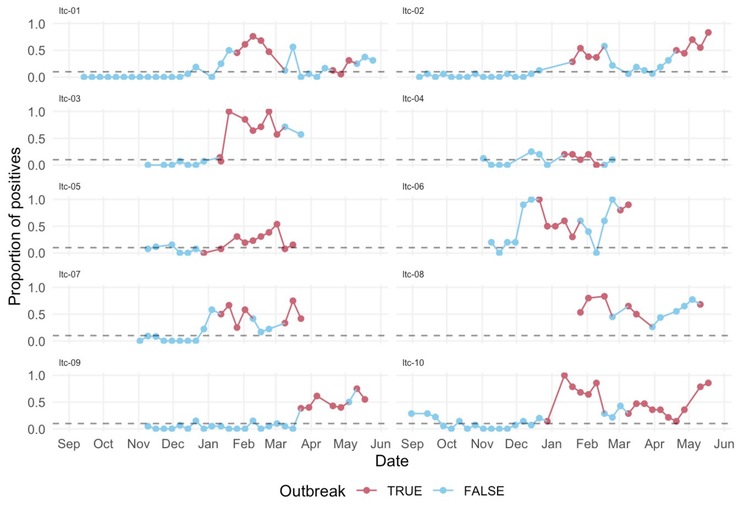


Figure 1. A graphical representation of swab positivity for SARS-CoV2 over time



The median duration of an outbreak was 35 days and 18 (95%) involved both residents and workers, with the median number of cases being 34 (range: 2-150). For swabs performed during outbreak periods, the prevalence of positive swabs was 50% (47-53), with a median Cq of 37.3 (IQR 35.2-38.7) (table 2). For swabs performed during non-outbreak periods, the prevalence of positive swabs was 18% (17-20), with a median Cq of 38.0 (IQR 36.4-39.1). The median Cq of swabs during non-outbreak periods was significantly lower ($p<0.01$), indicating a higher quantity of viral RNA sampled, during outbreak periods compared to non-outbreak periods. No outbreaks only involved staff and not residents.

For swabs performed during periods with identified staff cases (within 72 hours of case detection) but no resident-level cases or outbreaks, the prevalence of positive swabs was 12.8% (9.4-17.1), and with a median Cq of 38 (IQR 36.4-38.7). Four LTCHs had staff cases that did not lead to an outbreak and when there were staff cases the swab positivity was 28.8% (IQR 18.8-41.4) in worker-only areas (e.g., locker rooms, staff dining areas) compared to 8.7% (5.7%-13%) for swabs performed in areas that included both staff and residents.

The percentage of positive swabs increased in the days and weeks prior to an outbreak being identified by the LTCH (Table 3). The percentage of positive swabs also decreased in the days and weeks after an outbreak was identified by the LTCH (Table 3). Among eight LTCHs with an outbreak and swabs performed in the weeks prior to the outbreak starting, five of the homes had floor swab positivity exceeding 10% five or more days prior to the outbreak being identified (Figure 1). For three of these five LTCHs, positivity of floor swabs exceeded 10% more than 10 days before the outbreak was identified.

We generated receiver operating characteristic (ROC) curves for the primary outcome (presence of outbreak in a given week) using the proportion of swabs positive for SARS-CoV-2 and this yielded an area under the ROC of 0.85 (95% CI: 0.78-0.92). The PPV, NPV, specificity and sensitivity are provided in Table 4 across five thresholds of swab positivity (i.e., 10%, 20%, 30%, 40%, and 50%) and displayed graphically across all thresholds (Figure 2). The percentage of positive swabs was not associated with CO2 levels in PPM (Appendix). For swabs performed during periods with no identified staff or resident-level cases and no outbreak, the prevalence of positive swabs was 18.9% (17.3-20.6), with a median Cq of 38 (IQR 36.3-39.1).

In this multicenter prospective study, we found that detection of SARS-CoV-2 from the built environment was strongly associated with COVID-19 outbreaks. Furthermore, the rising proportion of positive floor swabs preceded the formal recognition of an outbreak by at least 5 days in a significant fraction of outbreaks. In addition, the prevalence of positive floor swabs for SARS-CoV-2 also declined after the cessation of outbreaks. These results suggest that built environment SARS-CoV-2 testing could be a valuable tool for identifying and monitoring of SARS-CoV-2 outbreaks in LTCHs.

Conclusions

1. **High levels of detection of SARS-CoV-2 from floor swabs was strongly predictive of outbreak status in long-term care homes.**
2. **The ability to discriminate between outbreak and non-outbreak status using built environment swabs was high, with AUROC of 0.85.**
3. **Swab positivity anticipated identified outbreaks in the majority of outbreaks evaluated, typically by 1-2 weeks.**
4. **Swab positivity was spatially localized, where in the case of work only cases, swab positivity was largely restricted to only worker areas.**
5. **Built environment testing of long-term care homes may be a viable option for future outbreak screening without the costs or invasive nature of individual testing.**