ORIGINAL RESEARCH

COVID-19 screening and outcomes at hospitals in a large Canadian health authority

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ABSTRACT

Background: This study investigates factors associated with COVID-19 positivity among patients admitted to hospitals in British Columbia, Canada, and analyzes patient outcomes based on their screening question responses.

Methods: We conducted a retrospective analysis of patients admitted to 12 hospital emergency departments between November 1, 2020, and June 30, 2022. Patients who tested positive for SARS-CoV-2 through PCR within 48 hours of admission were categorized as positive cases. Covariates included age, geographical region, and the era of the COVID-19 pandemic.

Results: Among the 88,511 unique admissions, 8.6% (7,642) tested positive for COVID-19. Patients who met screening criteria were 4.7 times more likely to test positive. Patients in the later stages of the pandemic were less likely to be identified through screening questions. Patients who tested positive were 1.5 times more likely to die than those who tested negative, although patients who tested positive in later pandemic stages had lower overall mortality rates.

Conclusion: While patients testing positive on admission were more likely to meet screening criteria and had a higher risk of mortality, the screening process missed half of all positive cases (3,907 patients). Implementing universal testing increased resource demands but identified the positive cases missed by screening alone, allowing for the implementation of precautionary measures to prevent potential transmission. Ultimately, the decision to implement universal testing should consider resource allocation, community prevalence, and patient demographics.

KEYWORDS
COVID-19, screening, SARS-CoV-2, hospital

INTRODUCTION

In late 2019, a novel coronavirus pathogen, SARS-CoV-2 emerged from Wuhan, China causing the disease COVID-19 which can lead to severe pneumonia-like infection (Shanmugaraj *et al.*, 2020). This pathogen rapidly spread globally and led to a pandemic declaration by the World Health Organization (WHO) in March 2020 (Sanyaolu *et al.*, 2021). The first reported case of COVID-19 in Canada was published in a February 2020 case report, identified in a patient who had recently returned from a three-month visit to Wuhan (Silverstein *et al.*, 2020). By mid-2020, the pandemic had spread throughout the country, with over 100,000 reported cases and nearly 9,000 deaths (Government of Canada, 2023b). By September 2023, there were over 4.5 million reported COVID-19 cases in Canada, including more than 50,000 deaths. These numbers are likely an underestimation due to the elimination of community-based testing and multiple comorbidities of hospitalized patients (Government of Canada, 2023a).

The COVID-19 pandemic created additional challenges for hospitals. Hospitalized patients faced increased transmission risks, contributing to overwhelmed healthcare systems during the early pandemic stages (Mo *et al.*, 2021). Part of the concern in healthcare settings is that many patients with COVID-19 did not present with symptoms and yet were still capable of transmission (Huff & Singh, 2020). Since SARS-CoV-2 was partly spread via asymptomatic and pre-symptomatic transmission, symptom-based admission screening practices commonly used for other infectious agents were inadequate. The difficulty in identifying carriers led to various strategies being employed at different sites, placing particular importance on universal admission testing for SARS-CoV-2 (Stessel *et al.*, 2021). Universal admission testing was often used in conjunction with other screening measures, or as a temporary standalone practice. Universal admission testing, in conjunction with admission screening questions, may be used to inform when to eliminate mandatory testing and to assess how likely these questions are to identify subsequent positive patients. However, much of the literature reporting on similar questions has not been comprehensive, and has primarily involved a small, time-limited area (Scheier *et al.*, 2021; Wee *et al.*, 2020), or being limited to testing in a specific type of service delivery (Figueiredo *et al.*, 2020; Huybens *et al.*, 2020).

Conflict of interest: None.

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This study aimed to investigate the adequacy of screening questions to identify SARS-CoV-2 cases, along with outcomes for hospitalized patients, comparing those with COVID-19 to those without a positive specimen. Over the course of this study, we aimed to answer the following research questions:

- Q1: What are the factors associated with patients who tested PCR positive for SARS-CoV-2 upon hospital admission?
- Q2: What factors are associated with whether a patient was identified as potentially positive due to screening question response?
- Q3: Were patients with a positive SARS-CoV-2 PCR test more likely to die during their hospital stay compared to others?

METHODS

Study setting

Fraser Health is the largest health authority in British Columbia, Canada. It provides publicly funded healthcare services to nearly 2 million people. The setting for this study comprised 12 acute care hospitals within Fraser Health, with over 3,600 beds across three regions: North, South, and East. During the pandemic, all Fraser Health acute hospitals implemented universal admission testing for all patients entering through the emergency department (ED) and direct surgical admissions. Universal testing took place from November 2020 to July 2022. During this period, SARS-CoV-2-positive patients were cohorted and placed on droplet precautions in dedicated units with specialized staffing. Droplet precautions are practices to prevent the spread of respiratory infections and involve placing patients away from others, with staff using appropriate personal protective equipment such as surgical masks, face shield, gown, and gloves (Fraser Health Authority, 2022). This study was conducted as a quality improvement initiative to support infection surveillance, thus obtaining exemption from ethics review.

Study design

This study was a retrospective analysis of all ED patients admitted to Fraser Health hospitals from November 1, 2020, to June 30, 2022. During this time of universal admission testing, Fraser Health also had the policy of delivering admission screening questions to all patients. The screening included the following questions to flag patients deemed at higher risk of having COVID-19:

- *Did the patient exhibit any respiratory symptoms at the time of admission?*
- *Has the patient been asked to isolate in the past 14 days?*
- *Has the patient had a positive COVID-19 test in the past 20 days?*
- *Has the patient travelled outside the region in the past 14 days?*

These questions were used to place patients on droplet and contact precautions pending the result of the admission test. Admission data, laboratory screening data, screening question responses and discharge disposition were extracted from electronic health records at the patient level. Whole genome sequencing data was obtained from weekly surveillance reports from the provincial laboratory to understand the common strains circulating throughout the community over different time periods (British Columbia Centre for Disease Control, 2023).

Case definitions

A patient was considered COVID-19 positive on admission if they had a PCR-positive SARS-CoV-2 test in the first 48 hours after admission to a hospital. Each admission was counted a single time, while each patient could present more than once in the dataset if admitted more than once during the study period and met case definitions for a new case. Inclusion criteria was the following:

- Patients who were admitted to any of the 12 hospitals through the ED and surgery.
- Patients who were older than 6 years of age at time of admission.

Exclusion criteria was as follows:

- Patients admitted directly to a hospital who did not enter via the ED.
- Patients who were 6 years old or younger as these patients were not included in routine admission testing.
- Patients with a positive SARS-CoV-2 test in the 60 days prior to admission as this was the health authority's criteria for residual case at the time. This shorter than standard window was used by the health authority out of precaution for management of acute care inpatients.

The selection process and associated results are shown in Figure 1.

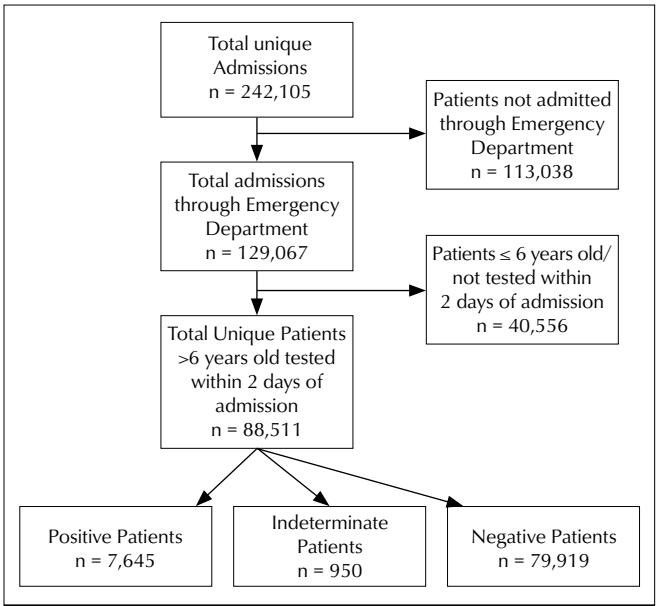

Figure 1: Flowchart of patient categorization.

Outcome variables

There were three variables used in this study to determine the outcomes of patients.

- **COVID-19 test result:** Patients were classified as follows: positive if the patient had a positive PCR within 48 hours of admission and no positive PCR in the 60 days prior; inconclusive, if the PCR test had a high Ct-value

(above 37 amplification cycles) and was not classified as a positive specimen by the laboratory; negative if all tests were negative within 48 hours of admission.

- **Screening response:** whether the patient answered yes to any of the COVID-19 screening questions and was classified into *met, did not meet, unable to assess.*
- **Death:** Whether the discharge disposition for the patient was expired.

Independent variables and covariates

Patient age at time of admission was categorized into groups following the common schema used in provincial reports. The main circulating variant strain was gathered from provincial reports, and used to track the evolving state of the pandemic (British Columbia Centre for Disease Control, 2023). Regions were defined by the area of the health authority in which each hospital was located to identify any geographical trends.

Statistical analysis

All data analyses were conducted at the individual admission level, with higher-level controls applied to assess individual patient risk factors. Descriptive analysis was conducted for each variable, followed by crude analysis using simple logistic regression for each of the three outcome variables to determine uncontrolled relationships. Multivariable logistic regression models were then built for each outcome variable to control for confounding and interaction effects. All covariates were kept in the model regardless of statistical significance due to conceptual importance. A p-value of <0.05 was considered statistically significant in the results. All analyses used R Statistical software (R Core Team, 2021).

RESULTS

Descriptive results

A total of 88,511 admissions were deemed eligible for the study, consisting of 7,642 (8.6%) admissions with positive PCR tests, 950 (1.1%) with inconclusive results, and 79,919 (90.3%) with negative PCR tests. The monthly test positivity rate at admission ranged from 1.0% to 29.3%, with a median of 6.6% (IQR: 5.3, 8.6%), shown in Figure 2. Descriptive results for exposure variables are shown in Table 1.

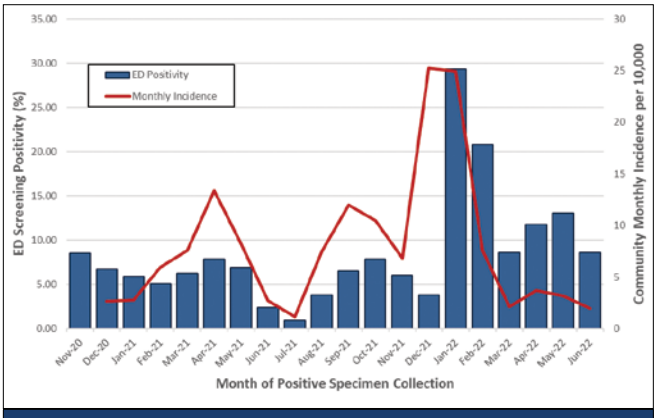

Figure 2: Admission screening positivity by month.

Table 1: Descriptive data for model variables

Variable Name	Values	Proportional Breakdown
COVID-19 era	Wild Type (Nov 2020 to Feb 2021)	16.1%
	Alpha (Mar 2021 to May 2021)	16.4%
	Gamma (Jun 2021)	5.6%
	Delta (Jul 2021 to Oct 2021)	24.7%
	Omicron (Dec 2021 to Jun 2022)	37.2%
Patient age category	6-19	3.2%
	19-39	14.8%
	40-59	19.8%
	60-79	36.1%
	80+	26.0%
Geographical region	East	31.4%
	North	35.8%
	South	32.8%
Screening response	Met screening criteria	18.5%
	Did not meet screening criteria	76.2%
	Unable to assess	5.3%
Discharge disposition	Discharged to morgue	5.8%
	Discharged elsewhere	94.2%

Analytical results

The sensitivity of the screening questions during the study period was 0.47 (95%CI: 0.45, 0.48), while specificity was 0.83 (95%CI: 0.83, 0.83). The positive predictive value of the screening questions was 0.21 (95%CI: 0.20, 0.22), and the negative predictive value was 0.94 (95%CI: 0.94, 0.94). While it was more likely to detect SARS-CoV-2 in patients who failed screening, using the screening questions alone would have resulted in missing over half of all positive patients.

Positive test result

After adjusting for sex, age, and region, patients who met the ED screening criteria were much more likely to test positive than those who did not meet the criteria. Patients who met screening criteria were 4.7 times more likely to test positive, yet over half of all COVID-19 positive patients did not meet these initial screening criteria. Additionally, patients were more likely to test positive in the later stages of the pandemic compared to the early stages. This trend aligns with increased community prevalence, as incidence rates ranged from under one case per 100,000 during the Delta era to over 78 cases per 100,000 during the Omicron era. A monthly summary of these incidence rates is overlaid with the ED positivity rate in Figure 2. In later stages of the pandemic,

Table 2: Results for controlled models			
	Odds Ratio (95% Confidence Interval)		
Risk Factors	**Positive Test Result**	**Met Screening Criteria**	**Death**
Admission Test Result			
Negative (reference)			-
Indeterminate			1.00 (0.73, 1.33)
Positive			1.50 (1.37, 1.64)‡
Met Screening Criteria			
No (reference)	-	-	-
Yes	4.67 (4.43, 4.92)‡		1.74 (1.62, 1.86)
Unable to Assess	1.26 (1.11, 1.41)‡		4.12 (4.12, 4.54)
COVID-19 Era			
Pre-Variant of Concern (reference)	-	-	-
Alpha	1.27 (1.16, 1.40)‡	0.86 (0.69, 1.06)	0.79 (0.72, 0.87)‡
Gamma	0.53 (0.43, 0.64)‡	0.23 (0.15, 0.35)‡	0.67 (0.58, 0.78)‡
Delta	1.09 (0.99, 1.19)	0.37 (0.30, 0.45)‡	0.84 (0.77, 0.92)‡
Omicron	3.21 (2.98, 3.47)‡	0.14 (0.12, 0.17)‡	0.71 (0.65, 0.77)‡
Age Category			
<19 (reference)	-	-	-
19-39	2.31 (1.85, 2.91)‡	1.32 (0.78, 2.29)	24.57 (5.50, 432.64)‡
40-59	3.26 (2.63, 4.10)‡	1.93 (1.16, 3.31)*	68.06 (15.40, 1195.06)‡
60-79	3.17 (2.56, 3.97)‡	2.18 (1.32, 3.72)†	171.18 (38.84, 3003.09)‡
80+	3.25 (2.62, 4.07)‡	1.80 (1.09, 3.09)*	363.35 (82.47, 6373.94)‡
Region			
East (reference)	-	-	-
North	0.74 (0.69, 0.78)‡	1.42 (1.25, 1.61)‡	1.02 (0.95, 1.09)
South	0.95 (0.90, 1.01)	1.18 (1.04, 1.33)†	0.98 (0.91, 1.05)

*: p<0.05, †: p<0.01, ‡: p<0.001

community PCR screening became uncommon, so reported incidence during this period is inaccurate.

Met screening criteria in positive patients

In the subset of the study population with a positive test, the adjusted model showed that the effectiveness of screening questions decreased over time. Compared to the initial wave of the pandemic (Wild Type Era), patients were less likely to be identified in the Delta era (37%) and even less likely in the Omicron era (14%). Compared to the reference region, the North region was 1.42 times more likely and the South region 1.18 times more likely to identify positive patients through screening.

Death

Patients who tested positive on admission screening were 1.5 times (95%CI: 1.37, 1.64) more likely to die from any cause compared to patients who tested negative. This relationship held true after adjusting for patient age, region, and wave of the pandemic. As the pandemic progressed, we observed a 30% reduction in death for all patients in the Omicron wave with patients less likely to die compared to the initial stage of the pandemic.

DISCUSSION

This study identified several key trends related to admission testing at hospitals and its effectiveness in detecting COVID-19 patients. Symptom-based and other risk-based screening methods were not found to be comprehensive for identifying patients likely infected with SARS-CoV-2. While it is true that patients who met the screening criteria were nearly five times as likely to be positive than those who didn't, this still missed over half of positive patients. With asymptomatic and pre-symptomatic cases comprising a large portion of COVID-19 cases (Yanes-Lane *et al.*, 2020), future patients may be overlooked if screening remains risk-based. Although asymptomatic cases are thought to be less likely to cause transmission than symptomatic ones (Byambasuren *et al.*, 2020), the risk remains and could still pose a threat to hospitalized patients. The efficacy of using patient symptoms as a screening tool was questioned early in the pandemic (Callahan *et al.*, 2020), with research showing that individual symptoms are poor predictors of COVID-19 and do not support testing (Struyf *et al.*, 2021). While this study found that multivariable prediction models have higher sensitivity

(Struyf *et al.*, 2021), the implementation for routine use may be challenging. Additionally, as the pandemic progressed, it was observed that patients were much more likely to test positive. This increase was expected as population saturation grew, with average daily COVID-19 incidence nearly four times higher than during earlier stages of the pandemic.

If only using risk-based screening during this period, 3,907 positive patients would potentially have been admitted without droplet and contact precautions, risking transmission within the hospitals. Although the screening questions showed limited sensitivity, combining them with supplementary measures – such as adding more risk-based questions and intensifying testing during high community prevalence – could improve the detection of positive patients. Among positive patients correctly identified by screening questions, several trends emerged. As the pandemic progressed, patients were less likely to be identified via screening questions. It is unclear whether this trend resulted from later waves of COVID-19 being less severe (Hyams *et al.*, 2023), changes in contact tracing, or increased vaccination rates, which may have led to milder symptoms in positive patients (Li *et al.*, 2022). We observed regional differences in the effectiveness of screening tests for detecting positive patients. This variation may be due to differences in the epidemiology of SARS-CoV-2 across regions of the health authority. This finding aligns with literature showing racial and socioeconomic disparities in both incidence and severe outcomes of COVID-19 (Khanijahani *et al.*, 2021). We found that positive test rates were lower in the North region compared to the East and South regions.

We observed that patients who tested positive for COVID-19 on admission were 50% more likely to die during their hospital stay compared to those who tested negative. This relationship remained after controlling for other factors, such as age and era of COVID-19. Notably, 708 (9.3%) of patients with COVID-19 died during their stay, compared to 4,402 (5.4%) patients who did not have COVID-19. It was suspected that this may be due to older patients being more likely to have been infected, as well as more likely to die, but after controlling for age this was not shown to be true. All-cause mortality (as opposed to cause-specific mortality) was chosen for this outcome measure for two reasons: to allow comparison of overall proportion of death between infected and uninfected groups, and to avoid subjectivity in assessing whether deaths were attributable to COVID-19 (Wang *et al.*, 2022). Additionally, as the pandemic progressed, we saw lower proportion of patients dying of any cause, which may indicate that later variants had less severe effects on infected patients.

There are some limitations that must be addressed to properly interpret the results of this study. The study occurred during a specific time and place, and the results identified may not be extrapolated beyond this. Universal testing was implemented at the height of the pandemic, and out of an abundance of caution, we decided to test all patients upon hospital admission. As this is no longer the case, and as COVID-19 symptoms have evolved over time (Torabi *et al.*, 2023), screening questions may no longer identify cases at the same rate as above. Another limitation is that the screening questions changed over time. These questions were not designed by the investigators, making them less specific than ideal. The interpretation of the screening questions likely varied between individual screeners. Additionally, the results found here may be specific to this region of British Columbia and may not be representative of other areas.

Universal testing in Fraser Health was discontinued in June 2022 due to shifts in COVID-19 epidemiology and changes in regional and global pandemic management. Although testing increased resource use – both through screening and additional precautions for positive and pending cases, it successfully identified many patients who might have otherwise been missed. Identifying asymptomatic patients enabled the early implementation of precautions, potentially preventing further transmission. Ultimately, the decision to conduct universal testing must be a balance of the resources required, community prevalence and patient population.

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