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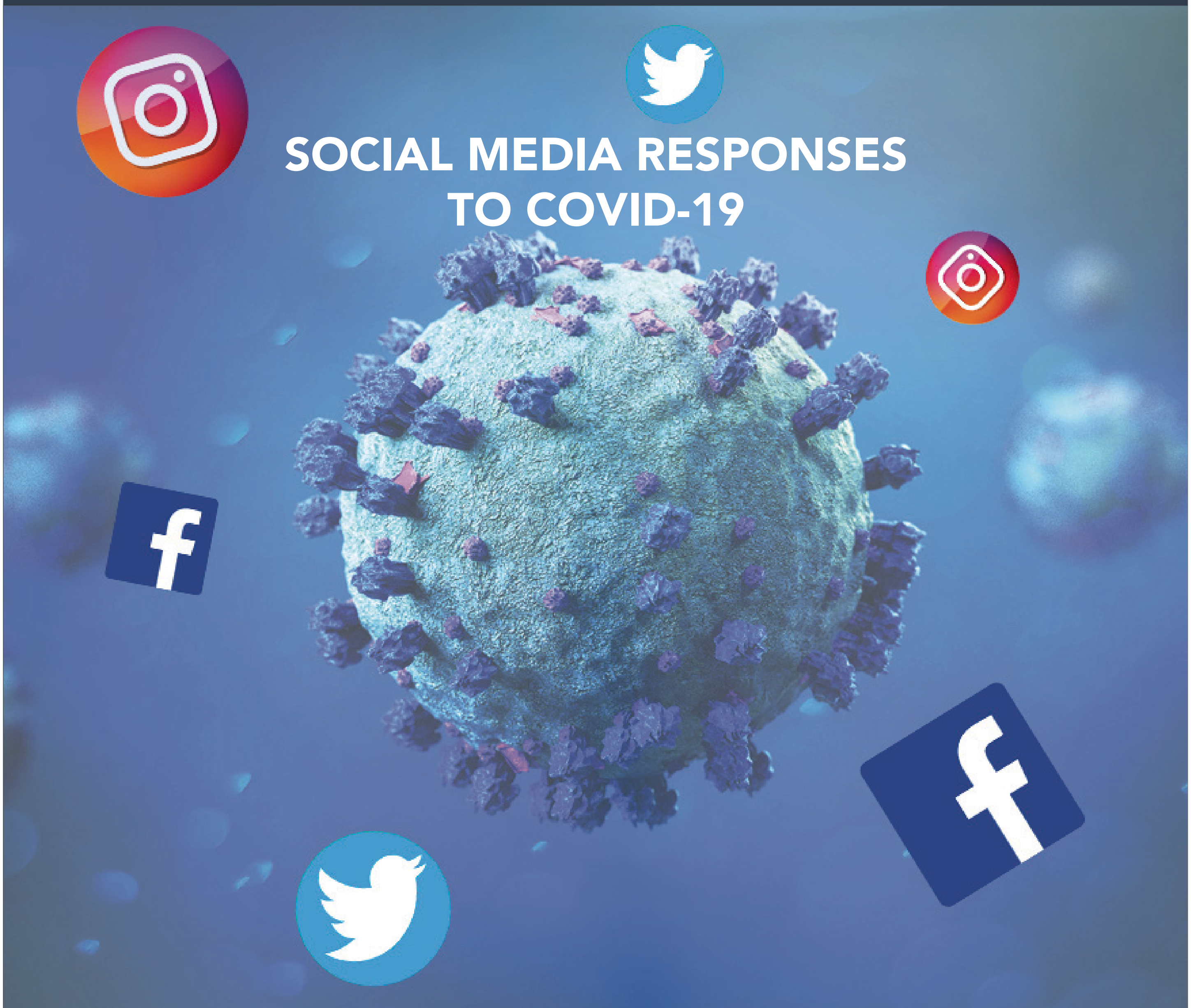

SOCIAL MEDIA RESPONSES TO COVID-19

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SOCIAL MEDIA RESPONSES TO COVID-19

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The hepatitis C epidemic in Canada: An overview of recent trends in surveillance, injection drug use, harm reduction and treatment

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Abstract

Hepatitis C continues to be a significant public health concern in Canada, with the hepatitis C virus (HCV) responsible for more life-years lost than all other infectious diseases in Canada. An increase in reported hepatitis C infections was observed between 2014 and 2018. Here, we present changing epidemiological trends and discuss risk factors for hepatitis C acquisition in Canada that may have contributed to this increase in reported hepatitis C infections, focusing on injection drug use. We describe a decrease in the use of borrowed needles or syringes coupled with an increase in using other used injection drug use equipment. Also, an increased prevalence of injection drug use and use of prescription opioid and methamphetamine injection by people who inject drugs (PWID) may be increasing the risk of HCV acquisition. At the same time, while harm reduction coverage appears to have increased in Canada in recent years, gaps in access and coverage remain. We also consider how direct-acting antiviral (DAA) eligibility expansion may have affected hepatitis C rates from 2014 to 2018. Finally, we present new surveillance trends observed in 2019 and discuss how the coronavirus disease 2019 (COVID-19) pandemic may affect hepatitis C case counts from 2020 onwards. Continual efforts to i) enhance hepatitis C surveillance and ii) strengthen the reach, effectiveness, and adoption of hepatitis C prevention and treatment services across Canada are vital to reducing HCV transmission among PWID and achieving Canada's HCV elimination targets by 2030.

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Introduction

Hepatitis C is a preventable and, in almost all cases, curable liver infection. Despite this, hepatitis C is responsible for more life-years lost than any other infectious disease in Canada (1–3). Researchers estimate that, in 2017, at least one person was infected with the hepatitis C virus (HCV) every hour in Canada, and 194,500 Canadians were living with chronic hepatitis C (4). In June 2018, the federal, provincial and territorial ministers of health released the *Pan-Canadian Sexually Transmitted and Blood-borne Infections Framework for Action* (5). The Framework endorses the World Health Organization's target to eliminate viral hepatitis as a public health threat by 2030, including achieving a 90% reduction in new cases of chronic hepatitis C infections by 2030 (5).

Hepatitis C is a nationally notifiable disease monitored by the Public Health Agency of Canada (PHAC). The Agency reports annually on trends in reported hepatitis C cases overall and by age, sex and province or territory. Surveillance data show a 14% increase in the reported national hepatitis C rate, from 29.4 per 100,000 people in 2014 to 33.6 per 100,000 people in 2018 (6), representing a total of acute, chronic and unspecified hepatitis C cases. In addition, from 2014 to 2018, the reported hepatitis C rates increased faster for females than for males (20% vs 10% increase) (6).

This article summarizes several trends and factors that may have influenced the rising hepatitis C rates between 2014 and 2018. While several factors are associated with the risk of hepatitis C acquisition, injection drug use is the most common risk factor for new infections in Canada (7–9). In this overview, we describe changes in injection drug use patterns and practices as well as in harm reduction services and practices. We also consider the impact—recent and potential—of expanding direct-acting antiviral (DAA) eligibility on hepatitis C rates. Finally, we discuss surveillance trends from 2018 to 2019 and the potential impact of the coronavirus disease 2019 (COVID-19) pandemic on the hepatitis C epidemic in Canada.

A changing landscape: Injection drug use on the rise

An estimated 1% of Canada's population have ever injected drugs (10) and about 0.3% were using injection drugs in 2014 (11). PHAC estimated that people who inject drugs (PWID) made up almost half of those who ever had a hepatitis C infection in 2017 (4). Based on data from 2000 to 2016, PWID make up between 60% and 85% of all new HCV infections in Canada (7–9). The sharing of needles, syringes and other injection equipment appears to be the primary driver of HCV transmission in Canada today (7–9). A modelling study estimated that the PWID population in Canada increased by 32% between 2011 and 2016 (11).

Injection drug use, social determinants of health and key populations

Injection drug use is associated with a history of trauma and family instability (12,13), transactional sex (12,13), food insecurity (14,15), incarceration (12,16), insecure housing (12,17–23), low income (12,17,20,24), lower levels of education (12), systemic discrimination (12,24) and unemployment (21,23,25).

Indigenous peoples bear a disproportionate burden of substance use disorders and associated harms in Canada, a situation that is associated with structural injustices rooted in colonization. Available evidence suggests Indigenous peoples are overrepresented among PWID in several regions in Canada (12,26–29). Estimates show that Indigenous youth (aged 24 years and younger) make up between 70% and 80% of new HCV infections among young PWID in Canada (30–32).

Gay, bisexual and other men who have sex with men (gbMSM) are an emerging population at risk for hepatitis C (33,34). An estimated 5% of gbMSM have a past or current HCV infection (35). Injection drug use appears to be the leading risk factor for hepatitis C in this population in Canada (33), though sexual transmission in the context of certain sexual practices associated with a risk of exposure via blood has also been known to occur, particularly among gbMSM living with HIV (36–38).

Understanding evolving behaviours related to HCV acquisition is essential to understanding the evolving hepatitis C epidemic among PWID.

Increased prevalence of prescription opioid injection and methamphetamine use among people who inject drugs

Substance use patterns in North America have been described in terms of "twin epidemics," comprising the opioid crisis, which has been responsible for a significant burden of morbidity and mortality among PWID in Canada over the past two decades (39), and an apparent resurgence of psychostimulant use and related harms since 2017 (40). In the most recent bio-behavioural Tracks survey of PWID in Canada (Phase 4: 2017–2019), the five most frequently reported injected drugs (in the six months before the survey) were cocaine (60.0%), hydromorphone (50.1%), methamphetamine (43.5%), morphine (41.6%) and heroin (32.4%). Of note, hydromorphone, morphine and heroin are all opioids (12).

Although national prevalence estimates are not available, non-medical use of prescription opioids has become increasingly common among PWID in Canada over the past 15 years (41–43). One study from Montréal found that in a prospective cohort of PWID, the proportion reporting prescription opioid injection increased from 21% in 2004 to 75% in 2009. PWID who reported prescription opioid injection were more likely than PWID who were non-prescription opioid injection drug users to acquire hepatitis C (41). This increased risk may be in part due to more frequent injections and increased opportunities for sharing used injection equipment (42,44) among those who use prescription opioids, a cohort that tends to be younger and less experienced with injection drug use (41).

The prescription opioid epidemic may be accelerating the transition to injection drug use among younger people who use drugs (45). Several studies from the United States have found an association between the increasing use of injection prescription opioids and increased rates of hepatitis C infections, particularly among younger adults (<30 years old) and reproductive-aged females (46–48).

There has also been a reported increase in the prevalence of methamphetamine use in Canada over the past 15 years (12,49,50). In the Tracks survey of PWID in Canada, the proportion of participants injecting methamphetamine increased from 6.8% in Phase 1 (2003–2005) to 43.5% in Phase 4 (2017–2019) (12). Methamphetamine use has been associated with HCV transmission in Canadian studies (51,52) and linked to increased frequency of syringe sharing (53) and increased injection frequency (54). Rates of methamphetamine use vary widely across the country (50). The most pronounced increases appear to be in Western and Central Canada (50,55,56). In 2016, the Winnipeg region declared a hepatitis C outbreak linked to a dramatic increase in the use of methamphetamine (57–59).

Injection drug use equipment sharing practices are changing

The proportion of Tracks survey participants who reported borrowing used needles or syringes decreased from 20.2% in Phase 1 (2003–2005) to 11.6% in Phase 4 (2017–2019) (12). In contrast, the proportion of participants who reported borrowing other used injection equipment (water, filters, cookers, spoons, tourniquets, ties, swabs and acidifiers) increased by almost one-third between Phase 1 and 4 (from 29.8% to 38.0%) (12). This finding is a concern as the risk of HCV acquisition from sharing drug-preparation equipment is similar to that associated with syringe sharing (60) and persists in the absence of needle or syringe sharing (61). Some studies have linked prescription opioid injection use to increased sharing of other used injection equipment, specifically, the sharing of "washes" (the residue found on used filters and cookers) (42,61–63).

Harm reduction coverage across Canada is increasing, but gaps remain

In 2016, the federal minister of health announced an updated drug strategy for Canada, the Canadian Drugs and Substances Strategy (CDSS) (64,65). The CDSS puts an increased emphasis on public health in the Government of Canada's response to substance use, with harm reduction included as one of the pillars of the strategy in addition to prevention, treatment and enforcement (64,65). Increased federal action and investments to address substance use, overdose prevention, addictions, harm reduction and drug treatment followed the launch of the CDSS. In 2017, PHAC created the Harm Reduction Fund, one of the CDSS initiatives (66), to support community-based projects across Canada that help reduce HIV and hepatitis C acquisition and transmission among people who share injection and inhalation drug use equipment. Evidence-based harm reduction strategies, such as needle-and-syringe programs, opioid agonist therapy and supervised consumption services are essential to reducing the risk of HCV transmission and reinfection among PWID (67,68). The Phase 4 (2017–2019) Tracks survey of PWID found that 90.1% of participants reported using a needle-and-syringe distribution program, 47.3% used some form of opioid agonist therapy and 13.5% used a supervised consumption service in the 12 months before the survey (12).

One Canadian modelling study found that between 2011 and 2016, needle-and-syringe coverage increased from 193 to 291 needles and syringes per PWID (11). Opioid-agonist-therapy coverage increased from 55 to 66 recipients per 100 PWID, despite increasing injection drug use over this period (11). Based on these preliminary data, Canada appears to be meeting the World Health Organization's needle-and-syringe-program and opioid-agonist-therapy provision targets overall. However, coverage and access vary across provinces and territories (11,33).

Hepatitis C rates among females in Canada are on the rise

From 2014 to 2018, reported hepatitis C rates increased for both females and males (6). However, while rates were consistently higher among males, rates for females in 2018 were 20% higher than those in 2014; while rates for males were 10% higher. Also, women aged 25 to 39 years old showed the largest hepatitis C rate increases in Manitoba, Ontario, Québec, New Brunswick and Yukon during this time. Similarly, during the same period, higher rate increases of other sexually transmitted and bloodborne infections (STBBI), such as syphilis and HIV, were reported among females compared to males in several jurisdictions (69,70). Several studies from the United States have also reported an increase in hepatitis C rates among reproductive-age females in recent years, a trend that has been linked to the opioid crisis (46–48).

While the bio-behavioural surveillance data from Phase 4 of the Tracks survey of PWID found that the proportion who self-reported borrowing other used injecting equipment in the past six months was 45.9% for cisgender females versus 33.7% for cisgender males (12), understanding what is driving these increasing rates among females is challenging for three main reasons: i) national routine surveillance data do not include risk factor data; ii) no testing volume data are available; and iii) Canadian research to contextualize this trend is limited.

Low hepatitis C treatment rates, expansion of direct-acting antivirals and its potential impact on future hepatitis C rates among the people who inject drugs community

According to the 2017–2019 PWID Tracks survey, 10.6% of PWID who were aware of their hepatitis C infection had ever taken hepatitis C treatment and 3.8% were currently receiving treatment (12). Low treatment rates are of concern for the health of the individual living with hepatitis C and the potential risk for HCV transmission.

There is substantial evidence demonstrating that PWID, including those with ongoing substance use, can be successfully treated for hepatitis C (71–73) particularly when treatment is delivered in a low-barrier setting and paired with wrap-around social and harm reduction supports (74–77). Moreover, Canadian modelling studies show that treatment can act as prevention in high-prevalence groups, such as PWID, especially when combined with opioid agonist therapy and high-coverage needle-and-syringe programs (78,79).

From 2014 to early 2018, Canadian hepatitis C treatment guidelines limited second-generation DAAs (with cure rates above 95% against the main HCV genotypes) to people with advanced liver fibrosis or cirrhosis (80). In June 2018, the

Canadian guidelines removed all disease-stage restrictions on DAA eligibility, making DAAs eligible for all people with chronic hepatitis C (81). However, the rollout of lifting disease-stage restrictions differed by province and territory, and other non-disease-stage restrictions remain and differ by province and territory (82,83). Although it is likely that expanded DAA eligibility may have contributed to an increase in hepatitis C testing across Canada from 2014 to 2018, there is, unfortunately, a lack of Canadian scientific evidence to support this hypothesis.

A study by Saeed *et al.* found that while hepatitis C treatment uptake increased dramatically among PWID after treatment restrictions were lifted in British Columbia, Ontario and Québec, uptake rates declined a year later (83). This was thought to reflect a "warehousing effect," as physicians began clearing the initial backlog of treatment-eligible individuals engaged in care who had been deferring treatment until DAAs became available (83). To this end, we need innovative and tailored programs and policies to successfully engage PWID in care and facilitate increased levels of treatment initiation (33,83–87).

The advent of DAAs has raised concerns about a potentially higher risk of reinfection in high-risk populations, such as PWID and HIV-positive gbMSM (88,89). However, concurrent harm reduction strategies and behavioural and structural interventions appear to reduce the risk of reinfection (72,74,77,90,91). The impact of DAA on treatment uptake and reinfection risk are both areas that warrant further scholarly attention and surveillance.

Anticipating the impact of the COVID-19 pandemic on hepatitis C in Canada

Evidence is already emerging that the COVID-19 pandemic and public health mitigation measures have adversely impacted the delivery of and demand for STBBI prevention, testing, treatment and harm reduction services in Canada (92). According to a 2020 PHAC survey of how the COVID-19 pandemic impacted the delivery of STBBI and harm reduction services in Canada, 21% of service providers providing support and treatment services for people living with HIV, hepatitis C or both experienced a decreased demand for and ability to deliver their services (92). In addition, 44% of STBBI prevention, testing and treatment service providers experienced a decrease in their ability to provide their services. Concurrently, 40% of harm reduction and drug treatment service providers reported an increase in demand for their services, although 63% reported no change or only a slight change in their ability to deliver their services (92). Given decreased access to HCV testing, this will likely impact the number of HCV diagnoses in 2020 and 2021, generating in underestimating the rate of newly reported hepatitis C cases. This would occur in the context of changing drug use practices generating from the pandemic's impact on harm reduction service availability and the quality and quantity of the drug supply, and COVID-related isolation requirements (93–97).

Conversely, the COVID-19 pandemic may generate in new opportunities for engagement in hepatitis C care. The same survey noted that 81% of STBBI-related service providers provided remote services since the beginning of the pandemic. Of these, 66% created new remote services during this period (92). The recent expansion of virtual care, if sustained, may present opportunities to improve access to hepatitis C care in the future, particularly for rural and remote populations (92,93,98), and could reduce wait times for accessing specialty care (99), enabling faster treatment scale-up. However, future monitoring and research will be needed to determine whether such virtual services have high uptake among PWID.

At the time of going to press, the latest available hepatitis C surveillance data showed the national reported hepatitis C rate had declined by 10% from 2018 to 2019 (100). Furthermore, all but two provinces and territories showed declining reported hepatitis C rates, of between −4% and −40% (Prince Edward Island's hepatitis C rates increased by 15% since 2018, and Nova Scotia's remained stable). Unfortunately, due to the impacts of the COVID-19 pandemic, it will be difficult to determine if the rate drop from 2018 to 2019 should be interpreted as a blip or a new trend.

Discussion

This overview article summarized several changing trends and risk factors associated with hepatitis C, with a strong focus on injection drug use practices. These trends and risk factors may partially explain the rising reported hepatitis C rates observed in Canada between 2014 and 2018. We also discussed how the staggered expansion of DAA eligibility across Canada may have contributed to an increase in hepatitis C testing and how this and the COVID-19 pandemic might influence future rates of reported hepatitis cases.

Limitations

This overview has several limitations: first, national surveillance data are limited to reported cases by age, sex and province or territory. It does not provide any risk factor data or differentiate between acute, chronic or reinfection cases. While injection drug use is the most commonly cited risk factor for hepatitis C, and thus the focus of this overview, there are other risk factors such as having received care in an hepatitis C–endemic area, other non-injection drug use, needle-stick injury among healthcare workers, having had a blood transfusion before 1992, sex practices that lead to blood exposure, and mother to child transmission (101). Changes associated with any of these risk factors may have also contributed to the observed increase in rates of reported cases from 2014 to 2018. However, there was insufficient literature to determine this.

Second, Canadian surveillance data do not include the number of people testing for hepatitis C, which would inform changes in testing practices over time. Finally, the surveys and papers reviewed used varying time points, and each came with its own set of limitations. For example, the Tracks surveys are cross-sectional and descriptive (12).

Conclusion

The continuous routine and enhanced bio-behavioural surveillance of hepatitis C are crucial for monitoring Canada's hepatitis C epidemic. Improvements to national surveillance data, including collecting risk factor and sociodemographic data and differentiating hepatitis C cases by infection status using standardized national definitions, would improve our understanding of the structural and behavioural risk factors driving HCV transmission in Canada. At the time of developing this overview, PHAC was reviewing the hepatitis C case definition in collaboration with provinces and territories and considering the feasibility of adding a reinfection case definition.

Furthermore, ongoing efforts to strengthen the reach, effectiveness and adoption of evidence-based hepatitis C prevention and treatment services across Canada are vital to reducing HCV transmission among high-risk PWID and achieving Canada's HCV elimination targets by 2030.

Authors' statement

LL — Conceptualization, research, writing, original draft, final draft, review, editing, supervision
MK— Conceptualization, research, writing, original draft, editing
JT — Editing, research
KS — Research, editing, reference management
MB — Review, editing
JA — Conceptualization, review, editing, supervision

Competing interests

None.

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Impact of school closures and re-openings on COVID-19 transmission

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Abstract

Background: Globally, the education of students at primary and secondary schools has been severely disrupted by the implementation of school closures to reduce the spread of coronavirus disease 2019 (COVID-19). The effectiveness of school closures in reducing transmission of COVID-19 and the impact of re-opening schools are unclear.

Methods: Research criteria for this rapid review included empirical studies, published or pre-published worldwide before January 25, 2021, that assessed the effectiveness of school closures in reducing the spread of COVID-19 and the impact of school re-openings on COVID-19 transmission.

Results: Twenty-four studies on the impact of school closures and re-openings on COVID-19 transmission were identified through the seven databases that were searched. Overall the evidence from these studies was mixed and varied due to several factors such as the time of implementation of public health measures, research design of included studies and variability among the levels of schooling examined.

Conclusion: Preliminary findings suggest that school closures have limited impact on reducing COVID-19 transmission, with other non-pharmaceutical interventions considered much more effective. However, due to the limitations of the studies, further research is needed to support the use of this public health measure in response to the COVID-19 pandemic.

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Introduction

As of March 11, 2020, the World Health Organization has declared the coronavirus disease 2019 (COVID-19) outbreak a pandemic (1). Globally, jurisdictions started to implement a variety of non-pharmaceutical interventions (NPIs) to limit the spread and the impact of COVID-19 disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Closing schools was one of the NPIs implemented; however, these closures not only disrupted the education and daily routines of students, but also the lives of teachers and parents.

While school closures have been implemented to combat the spread of COVID-19, they were also associated with negative effects on student's mental health and academic progress and lead to increased stress in parents and teachers (2). With a lack of school-based peer interactions and daily routines, it has been reported that students experience increased distress, loneliness, anxiety and depressive symptoms (2,3). School routines are crucial for maintaining the well-being of students, especially those with mental health or special education needs (4). In addition, school closures have been associated with reduced academic achievement due to delayed educational progress (3,5,6). It is uncertain whether virtual learning is equally effective and many students from low-income households lack access to, and accommodations with, online materials (6).

Given the negative impacts of school closures, it is important to consider whether they are significantly effective in reducing the impact of COVID-19. Initially, it was assumed that school closures would be effective in mitigating the spread of COVID-19 based on the evidence from both seasonal and epidemic influenza (7,8). In contrast, modelling studies conducted in Ontario and across Canada during the first and second waves found that school closures had limited impact on reducing the transmission of COVID-19 compared with other NPIs (9–11). Other modelling studies reported modest effects of school closures in delaying peak case numbers early in the pandemic (12,13), while some studies showed a smaller magnitude of effect when compared with other NPIs (14,15). Early modelling studies relied on the underlying assumption that there is a low transmission risk in children. Although modelling studies are excellent for making informed predictions, their accuracy is dependent on the assumptions and the quality of data used. Overall, there was a need to assess the potential impacts of school closures in reducing the spread of COVID-19.

This review summarizes empirical studies on the effectiveness of school closures and the impact of re-opening schools in reducing community transmission of COVID-19 and decreasing the incidence of COVID-19 in primary and secondary schools. The principal focus of this article was the impact of primary and secondary school closures, although if studies also included data from other types of schools this was included as well.

Methods

Our research criteria included empirical studies that assessed the impact of school closures and/or re-openings on COVID-19 that were published before January 25, 2021. Predictive modelling studies were excluded. Searches to retrieve relevant articles were conducted in PubMed, Scopus, BioRxiv, MedRxiv, ArXiv, SSRN and Research Square, by the Emerging Science Group of the Public Health Agency of Canada. Search terms included the following: school AND closure OR re-opening within a database of COVID-19 literature that is updated daily. References were also used to search for additional relevant studies. Included literature was confined to English and French languages. Articles (n=966) were then screened for relevance. A total of five observational studies and nineteen ecological studies were found to be relevant (see **Appendix Table A1** and **Table A2**).

Results

Twenty-four articles published prior to January 25, 2021 on the impact of school closures and/or re-openings on the spread of COVID-19, were identified. These included a cross-sectional study (16), two cohort studies (17,18), two cluster and outbreak investigations (19,20) and 19 ecological studies. Eleven of these studies are preprints or studies that have not yet been peer-reviewed. All studies identified in this review pre-date the identification of variants of concern.

Most observational studies assessing the impact of school closures/re-openings on the spread of COVID-19 in schools reported no significant effects (see Appendix Table A1). Four studies found no difference in incidence of cases both before and after closing schools for the holidays, following children who stayed at home vs those who went to school with strict surveillance, or following school re-opening (16–19). An outbreak investigation study reported a large outbreak from a high school in Israel, but this was confounded by the fact that the mask mandate was lifted just as there was a heatwave, which may have affected compliance with other recommended public health measures (20). Furthermore, it was noted that there was overcrowding in the high school that limited physical distancing, and extracurricular activities were not banned.

Of the ecological studies assessing community transmission (see Appendix Table A2), ten were conducted across multiple countries, five in the United States, two in Asia and two in Europe. Five studies reported that school closures and re-openings were not significantly associated with reduction in the transmission and incidence of COVID-19 and were much less effective in reducing transmission when compared with other NPIs (21–25). Four studies reported a reduction in the incidence of COVID-19 in the community ranging from 8% to 62% following school closures (26–29). Other studies reported a significant reduction in the effective reproduction number (R_t) (30–32). Three studies attributed significant reductions in mortality to school closures (29,33,34) and one study reported increased mortality with delayed school closures (35).

Discussion

Overall, the evidence from these studies was mixed and varied due to several factors. Based on the findings of the observational studies assessing the incidence of COVID-19 in schools, school closures and re-openings did not significantly contribute to COVID-19 transmission when infection prevention and control measures (IPAC) were implemented in schools. The IPAC measures implemented by the schools were similar across most of the observational studies and included masks, physical distancing, frequent cleaning, reduced class sizes and improved hand hygiene. The implementation of these measures in schools have been reported to act as a mediating variable because of the reduced transmission and risk of infection with IPAC measures (36).

The findings from the ecological studies assessing community transmission were inconsistent, with some studies reporting that school closures/re-openings were not significantly associated with reduction in transmission (21–25), and other studies reporting a significant reduction in R_t (30–32) and mortality (29,33,34). In several of these ecological studies, it was reported that other NPIs such as lockdowns, gathering bans, mask mandates, non-essential business closure and travel restrictions were more effective than school closures in reducing the transmission of COVID-19. Ecological studies are considered a low level of evidence due to the research design, the multiple confounding factors and the high degree of variability in the results. All of the ecological studies included in this review analyzed data on school closures/re-openings early in the pandemic, between January–August 2020, when multiple NPIs were implemented simultaneously. Therefore, it was not possible to isolate the impact of school closures/re-openings on the number of cases of COVID-19 in the community. Additionally, only one of the ecological studies described if there was adherence to IPAC measures in the schools (25). These factors likely contribute to the heterogeneity between studies.

An important limitation of this review was the inconsistencies in the levels of schooling that were included in each study, which may have increased the variability in measures of how effective school closures were across studies. Most studies did not provide information on what schools were included when determining the impact of school closures on the spread of COVID-19. Some studies measured primary and secondary school closures alone and some measured them in combination with post-secondary schools. The risk of transmission may have varied significantly between students in primary and secondary schools because of potential differences in their behaviours and adherence to IPAC measures with resultant difference in reduction of viral transmission. Transmission was found to be lower in primary schools relative to secondary schools, based on the results of one study in a review that assessed this (19). Although not specifically stated in the previous study, their results were in line with what we know about the use of IPAC to limit transmission in these settings (37). Additionally, the relative impact of school closures and re-openings have been shown to vary according to the time of implementation, level of community transmission, and the structure of populations from different countries.

Based on the empirical evidence summarized in this article, school closures had a small effect on limiting the spread of COVID-19 in schools and the community and appeared to be much less effective than other NPIs. These findings are also consistent with modelling studies conducted across Canada (9–15). The implementation of school closures is currently based on when the transmission of COVID-19 in the community is high—as dictated by local health jurisdictions; however, the role of school closures and re-opening in areas with low community transmission is less clear and should be studied further.

School closures may be associated with negative effects on student's mental health and academic progress (2); thus, public health decision makers should consider if the apparent low efficacy of school closures in reducing transmission outweighs the many negative consequences on students' well-being. Overall, the confidence in this evidence is low given that the studies in this review vary by several factors and were conducted at different times and in a number of countries. Finally, the study period of this review is also a limitation, as there are marked differences in the 3rd and 4th waves compared with the 1st and 2nd waves of COVID-19 with the introduction of more transmissible variants of concern. How the present evidence will compare with that obtained during periods of the spread of more transmissible variants of concern is not known at this time and will require further study.

Conclusion

The findings of this review may have implications for public health decision making and future research on mitigation strategies for schools. The preliminary evidence provided in this review suggests that school closures and re-openings may have only a limited impact on the transmission of COVID-19 within a community. However, there is still a high degree of uncertainty due to the high variation in the methodology and results across the various studies. Additional research is needed to further explore more systematically the impacts of school closures and to determine how and when they may be used most effectively in controlling the epidemic.

Important knowledge gaps to consider are how 1) the presence of new variants of concern and 2) the rollout of COVID-19 vaccinations will impact the transmission of COVID-19 within the schools and communities. The evidence presented in this article pre-dates the introduction of variants of concern; therefore, additional research is needed to understand how the emergence and spread of these variants will impact the effectiveness of school closures or what the impact of school re-openings will have on the spread of COVID-19.

Authors' statement

MEJ — Methodology, investigation, writing–original draft
RE — Conceptualization, writing–review and editing, supervision
LW — Writing–review and editing
PH — Writing–review and editing
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MS — Writing–review and editing
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Competing interests

None.

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Appendix: Tables

Appendix Table A1: Summary of observational studies assessing the impact of school closures or re-openings on the transmission of COVID-19 in schools and the community (n=5)

Study	Method	Key outcomes
Cohort studies (n=2)		
Gandini (2020) (17) Prospective cohort study and cross-sectional study Italy Sep–Nov 2020	This study analyzed the association between school re-opening dates and COVID-19 cases across twenty-one Italian regions by using a database on positive cases in elementary, middle and high schools and SARS-CoV-2 incidence in the general population. IPAC measures included temperature control, hand hygiene, mask mandate for students/staff, physical distancing, ban on sports and music and reduced duration of school. Several COVID-19 outcomes were measured during school re-openings: growth of incidence, R_t, and secondary infections.	There was no evidence that the second SARS-CoV-2 wave was driven by school re-openings across the regions. SARS-CoV-2 incidence among students was lower than the general population of all but two Italian regions. The increase in R_t was not associated with the different school opening dates. School closures implemented in two regions did not affect the decline of R_t.
Fontanet (2020) (18) Retrospective cohort study France Feb–Apr 2020	This retrospective cohort study included primary school pupils, teachers, non-teaching staff, parents and relatives exposed to SARS-CoV-2 in February and March from six schools. IPAC measures were not described. A questionnaire covering sociodemographic information and history of recent symptoms was completed by participants. Blood samples were also tested for the presence of anti-SARS-CoV-2 antibodies using a flow-cytometry-based assay. Three introductions of SARS-CoV-2 occurred prior to school closures. Spread within schools vs families was investigated in this sero-epidemiological study. IAR was compared between school contacts and family contacts to understand the potential impact of the school closure.	IAR was 45/510 (8.8%), 3/42 (7.1%), 1/28 (3.6%), 76/641 (11.9%) and 14/119 (11.8%) among primary school pupils, teachers, non-teaching staff, parents and relatives, respectively (p=0.29). No secondary infections from COVID-19 introductions in schools was detected among students and teachers. Among pupils who were infected, their parents were significantly more likely to be infected (61.0% versus 6.9%; p<0.0001), The same was identified among relatives of infected pupils compared with non-infected pupils (44.4% versus 9.1%; p=0.002). Transmission did not appear to be impacted by the closure of schools.
Cross-sectional studies (n=1)		
Kriger (2020) (16) Cross-sectional study Israel Mar–May 2020	During a national lockdown, an alternative school was used for healthcare workers' children to attend with strict symptom surveillance. Families with children who remained at home were compared with children at this alternative school. IPAC measures in the school included daily disinfecting, face mask use by staff and frequent hand washing. This cross-sectional study included 70 children who attended the alternative primary school and 36 who stayed home, along with their 78 parents. Data was collected through a short questionnaire; nasopharyngeal and oropharyngeal swabs were obtained and tested for SARS-CoV-2 by RT-PCR, and blood was collected for SARS-CoV-2 IgA and IgG titres.	Symptoms were reported in approximately 16% of children in both groups: those who attended the school (n=11/70) and those who did not (n=6/36). Positive serology tests showing previous exposure was detected in less than 2% of each group and they were not significantly different from each other. There was no evidence of increased infection in those at school compared with those at home.
Cluster and outbreak investigations (n=2)		
Larosa (2020) (19) Cluster investigation Italy Sep–Oct 2020	This cluster investigation analysed the transmission of COVID-19 in 41 classes of 36 schools upon their re-opening in northern Italy. The secondary attack rate was measured in students and teachers in elementary and secondary schools (middle and high schools). IPAC measures included: mask mandate for high school students only, physical distancing and ban of extracurricular activities.	Secondary attack rate for COVID-19 was reported to be higher in secondary schools (6.6%) than in elementary schools (0.38%).
Stein-Zamir (2020) (20) Outbreak investigation Israel May–Jun 2020	This outbreak investigation study assessed the epidemiological characteristics of a high school outbreak in Jerusalem that displayed mass COVID-19 transmission upon school reopening on May 17. The high school included grades 7–12. An extreme heatwave occurred upon the re-opening of the school. IPAC measures: face mask use was lifted for three days during the heatwave, physical distancing was below the standard in overcrowded classes, and extracurricular activities were not banned.	It was reported that the proportion of the 10–19 year-olds was 19.8% (n=938/4,747) of the cases before May 24th, and then increased to 40.9% (n=316/772) after May 24th. Testing of the whole school revealed that 153 students (attack rate: 13.2%) and 25 staff members (attack rate: 16.6%) were COVID-19 positive. COVID-19 rates were higher in students in grades 7–9 than in grades 10–12.

Abbreviations: COVID-19, coronavirus disease 2019; IAR, infection attack rate; IgA, immunoglobulin A; IgG, immunoglobulin G; IPAC, infection prevention and control; R_t, effective reproduction number; RT-PCR, reverse transcription polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2

Appendix Table A2: Summary of ecological studies assessing the effectiveness of school closures or re-openings on reducing spread of COVID-19 in the community (n=19)

Study	Method	Key outcomes
Global (n=10)		
An (2021) (21) Ecological study Global Jan–Jul 2020	This study aimed to identify associations between six NPIs and the number of COVID-19 infections. Using worldwide data on NPIs and COVID-19 infections between Jan–Jul 2020, analysis was conducted on the short- and long-term effects of NPIs on new infection rates five, nine, 12, and 21 days after their adoption. IPAC measures and level of schooling included in the study were not described. NPIs examined included mask mandates, international travel restrictions, domestic lockdowns, mass gathering bans, restaurant closures and school closures.	School closures took more time than other NPIs to show efficacy. After a time lag, the impact of school closures on new case rates was -0.492 (SE=0.16) at 12 days (p<0.01), -0.722 (SE=0.148) at 21 days (p<0.001), and -0.824 (SE=0.0967) at 30 days (p<0.001). School closures were not found to have significant effects on population-adjusted infections in the long-term (90th to 120th day).
Banholzer (2020) (27) Ecological study 20 countries Apr 2020	In this study, the impact of NPIs on the relative reduction of new COVID-19 cases using a Bayesian hierarchical model with a time-delayed effect for each NPI. IPAC measures were not described. NPIs examined included 1) primary school closures, 2) border closures, 3) public event bans, 4) gathering bans, 5) venue closures, 6) lockdowns prohibiting public movements without valid reason and 7) work bans on non-essential business activities.	The mean reduction of new COVID-19 cases with primary school closures was 8% (95% CI: 0%–23%). Compared with other NPIs examined, school closures appeared to be one of the least effective NPIs.
Banholzer (2021) (26) Ecological study 20 countries Feb–May 2020	Using a semi-mechanistic Bayesian hierarchical model, this study aimed to measure the effectiveness of seven NPIs in reducing the number of new infections. IPAC measures were not described. NPIs examined included 1) primary school closures, 2) border closures, 3) public event bans, 4) gathering bans, 5) venue closures, 6) lockdowns prohibiting public movements without valid reason and 7) work bans on non-essential business activities.	The relative reduction of new COVID-19 cases with primary school closures was 17% (95% CI: 2%–36%). This reduction was lower than two other NPIs (event bans and venue closures).
Brauner (2021) (28) Ecological study 41 countries Jan–May 2020	This study estimated the effectiveness of NPIs in 41 countries using a Bayesian hierarchical model by linking intervention implementation dates to national case and death counts. Intervention effect sizes were categorized by the median reductions in the R_t of less than 17.5% (small), between 17.5 and 35% (moderate) and at least 35% (large). NPIs examined included: limiting gatherings to fewer than 1,000 or fewer than 100 or fewer than 10, closing some businesses, closing most businesses, closing schools and universities, and stay at home orders. IPAC measures were not described.	The percentage reduction in R_t associated with closing both schools and universities in conjunction was 38% (95% CI: 16%–54%), which was categorized as a large effect size. The individual effects of school closures was not measured.
Klimek-Tulwin (2020) (38) Ecological study Global Mar 2020	This study aimed to assess the effect of school closures on COVID-19 cases globally by measuring correlation between the incidence rate on the day of school closure and the incidence rate in the following days. IPAC measures and level of schooling included in the study were not described.	The results indicate that there was a strong correlation between the day of educational facilities closure and the incidence rate in the following days (16th (p=0.004), 30th (p=0.002) and 60th (p=0.031) days since the 100th confirmed case in each country). Early closure of schools is statistically significantly correlated with lower incidence rates further on during the different phases of the epidemic.
Papadopoulos (2020) (39) Ecological study Global Jan–Apr 2020	The impact of lockdown measures was assessed globally using publicly available data. The timing and association of early NPIs with log_{10} national deaths (Log_D) and log_{10} national cases (Log_C) was compared between nations. IPAC measures and level of schooling included in the study were not described.	Early generalized school closure (p=0.050, regression coefficient ß=-0.012, 95% CI: 0%–-0.024%) was associated with reduced Log_C (log_{10} national cases).
Pasdar (2020) (34) Ecological study 22 countries May 2020	The aim of this study was to determine the associations between NPIs and COVID-19 outcomes. Associations with NPIs were assessed with their respective stringency index on several outcomes that form the epidemic curve: mean mortality rate, time to peak, peak deaths per 100,000 population, cumulative deaths after peak per 100,000 population and ratio of the mean slope of the descending curve to the mean slope of the ascending curve. IPAC measures and level of schooling included in the study were not described.	School closures were effective against all outcomes, except time to reaching the peak of the epidemic curve. The strongest association was seen in cumulative deaths after peak, per 100,000 (rs=-0.744, p=0.009). In non-European countries, school closures were most effective against mean mortality rate (rs=-0.757, p=0.049).
Esra (2020) (30) Ecological study Global Jan–May 2020	This study used globally reported data on SARS-CoV-2 cases to fit a Bayesian model framework to estimate the association with NPIs and transmission. NPIs examined include stay home mandates, gathering limits, school closures (primary, secondary and tertiary educational institutions) and mask policies. IPAC measures were not described.	There was an estimated mean reduction in R_t of 12% (95% CI: 5%–19%) with school closures (primary, secondary and tertiary educational institutions).

Appendix Table A2: Summary of ecological studies assessing the effectiveness of school closures or re-openings on reducing spread of COVID-19 in the community (n=19) (*continued*)

Study	Method	Key outcomes
Global (n=10) (*continued*)		
Jüni (2020) (40) Ecological study Global Mar 2020	This prospective study of geopolitical areas aimed to determine whether climate or public health interventions are associated with reducing transmission of COVID-19. A weighted random effects regression was used to determine the association between epidemic growth RRR and climate measures and public health interventions such as school closures, restrictions of mass gatherings and measures of social distancing during an exposure period 14 days previously. IPAC measures and level of schooling included in the study were not described.	Strong negative associations with epidemic growth were found for school closures (RRR - 0.63, 95% CI: 0.52%–0.78%). This association was more pronounced in areas that implemented two or three NPIs compared with one NPI.
Stokes (2020) (33) Ecological study Global Jun 2020	This study examined the variation of NPIs in 130 countries in two periods: 1) prior to first COVID-19 death and 2) 14-days-post first COVID-19 death. This study examined associations with daily COVID-19 deaths per million and each 24 day period (time between virus transmission and mortality). IPAC measures and level of schooling included in the study were not described.	Stricter/earlier school closures were associated with the largest reductions in COVID-19 deaths (-1.23 per million [95% CI: -2.20%–-0.27%]) compared with other NPIs.
North America (n=5)		
Auger (2020) (29) Ecological study US Mar–May 2020	This study aimed to determine if school closures were associated with a decrease in the cumulative incidence of COVID-19 and mortality. The impact of primary and secondary school closures was assessed using publicly available data from all 50 states. IPAC measures were not described.	Results showed that school closures were associated with a significant decline in incidence of COVID-19 (-62% [95% CI: -71%–-49%]) and in mortality (-58% [95% CI: -68%–-46%]). These associations were stronger in states with a low cumulative incidence of COVID-19 at the time of the school closure.
Dreher (2020) (31) Ecological study US Apr 2020	This study aimed to measure the impact of NPIs on the effective R_t of COVID-19 in US states. The average R_t was measured during the weeks after each state reached 500 cases. R_t was measured at the week immediately following 500[th] case (days +1 to +7) and at a one-week delay from 500[th] case (days +8 to +14). NPIs examined included stay at home order, educational facilities closure and non-essential business closure. IPAC measures and level of schooling included in the study were not described.	Educational facilities closure was associated with a significant reduction in R_t compared with states without this policy the week following 500 cases (ß=-0.17, 95% CI: -0.30%–-0.05%, *p*=0.009). From days 8 to 14 after the 500[th] case date, educational facilities closure was associated with a significant reduction in R_t compared with controls (ß=-0.12, 95% CI: -0.21%–-0.04%, *p*=0.006).
Krishnamachari (2020) (41) Ecological study US May 2020	This study aimed to examine the effects of NPIs on the cumulative incidence rates of COVID-19 in the US on a state-level in the 25 most populated cities, while adjusting for socio-demographic risk factors. A negative binomial regression was used to calculate adjusted rate ratios by comparing two levels of a binary variable: "above median value," and "median value and below" for days to implementing an NPI. NPIs assessed in this study included: days to closing of non-essential businesses, days to stay home orders, days to restrictions on gatherings, days to restaurant closings and days to schools closing. IPAC measures and level of schooling included in the study were not described.	Days to school closing was associated with cumulative incidence on days 35 and 42, with an adjusted rate ratio of 1.59 (95% CI: 1.03%–2.44%, *p*=0.04) at 35 days, and adjusted rate ratio of 1.64 (95% CI: 1.07%–2.52%, *p*=0.04) at 42 days. Delays in closing schools was positively associated with cumulative incidence at the state level.
Liu (2020) (22) Ecological study US Feb–Apr 2020	This study estimated the impact of nine different NPIs on reduction of the effective R_t by using the daily number of reported new cases and inferred infections in 50 states. IPAC measures and level of schooling included in the study were not described.	Closing schools was found to moderately reduce R_t by about 10% (95% CI: 7%–14%). This reduction was smaller than six other NPIs assessed (stay-at-home order, face masks, gathering ban, non-essential business closure, declaration of state of emergency and interstate travel restriction).
Yehya (2020) (35) Ecological study US Jan–Apr 2020	In this study, a state-level analysis was conducted to determine association between later implemented NPIs with higher mortality rates. Using a multivariable negative binomial regression, the association was tested between timing of emergency declarations and school closures with 28-day mortality. Day 1 for each state was set to when they recorded 10 or more deaths. IPAC measures and level of schooling included in the study were not described.	Later school closure was associated with more deaths (adjusted mortality rate ratio 1.05; 95% CI: 1.01%–1.09%; *p*=0.008).

Appendix Table A2: Summary of ecological studies assessing the effectiveness of school closures or re-openings on reducing spread of COVID-19 in the community (n=19) (*continued*)

Study	Method	Key outcomes
Asia (n=2)		
Cowling (2020) (32) Ecological study Hong Kong Jan–Feb 2020	This study examined the effect of public health interventions on the incidence of COVID-19 and on the daily effective R_t. Laboratory-confirmed COVID-19 cases and the daily effective R_t were estimated to determine changes in transmissibility over time. School closures included kindergartens up to tertiary and post-tertiary institutions, and tutorial centres. IPAC measures were not described.	The estimated R_t was 1.28 (95% CI: 1.26%–1.30%) during the 2-week period before the start of the school closures and 0.72 (95% CI: 0.70%–0.74%) during the first two weeks of school closures, corresponding to a 44% (95% CI: 34%–53%) reduction in transmissibility. R_t calculated from hospitalization data was 1.10 (1.06–1.12) before the start of the school closures and reduced to 0.73 (0.68–0.77) after school closures, corresponding to a 33% (95% CI: 24%–43%) reduction in transmissibility.
Kentaro (2020) (23) Ecological study Japan Mar 2020	This study aimed to assess the effectiveness of primary and secondary school closures on COVID-19 incidence nine days after implementation. IPAC measures were not described. Using a Bayesian method, time-series analyses were conducted, and local linear trend models were developed for the number of newly reported cases of COVID-19.	The school closure intervention was not effective in decreasing the incidence of COVID-19. The newly reported COVID-19 cases continued to rise (α - 0.08, 95% CI: -0.36%–0.65%).
Europe (n=2)		
Wieland (2020) (24) Ecological study Germany Mar–Apr 2020	The aim of this study was to assess the effectiveness of different NPIs against the spread of COVID-19 over time. School closures included day-care closures as well. IPAC measures were not described. Using publicly available data on daily reported German cases, exponential growth models for infections and R_t were estimated and investigated with respect to change points in the time series.	No significant effect was found on COVID-19 infections that could be attributed to school and day-care closures.
Ehrhardt (2020) (25) Ecological study Germany Feb–Aug 2020	This study aimed to assess the transmission of SARS-CoV-2 among children in primary schools, secondary schools and childcare facilities in Baden-Württemberg, Germany after school re-openings in May 2020. IPAC measures included: reduced class size, disinfecting, hand hygiene and banning of sports and music in primary and secondary schools. An epidemic curve was used to show daily new cases after the schools reopened.	Child-to-child transmission in schools was low. The study estimated that one secondary case originates per 25 infectious school days (days that cases spent at school during infectious period). School re-openings were not associated with a change in transmission of SARS-CoV-2.

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; IPAC, infection prevention and control; NPI, non-pharmaceutical intervention; RRR, ratios of rate ratios; rs, respective stringency index; R_t, effective reproduction number; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SE; standard error; US, United States

Among sheeples and antivaxxers: Social media responses to COVID-19 vaccine news posted by Canadian news organizations, and recommendations to counter vaccine hesitancy

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Abstract

Background: To create a successful public health initiative that counters vaccine hesitancy and promotes vaccine acceptance, it is essential to gain a strong understanding of the beliefs, attitudes and subjective risk perceptions of the population.

Methods: A qualitative analysis of coronavirus disease 2019 (COVID-19) vaccine discourse from 3,731 social media posts on the Twitter and Facebook accounts of six Canadian news organizations was used to identify the perceptions, attitudes, beliefs and intentions of Canadian news organizations' social media commenters toward taking a COVID-19 vaccine.

Results: Four main themes were identified: 1) COVID-19 vaccine safety and efficacy concerns; 2) conspiracy theories stemming from mistrust in government and other organizations; 3) a COVID-19 vaccine is unnecessary because the virus is not dangerous; and 4) trust in COVID-19 vaccines as a safe solution. Based on themes and subthemes, several key communication recommendations were developed for promotion of COVID-19 vaccine acceptance, including infographics championed by Public Health that highlight the benefits of the vaccine for those who have received it, public education about the contents and safety of the vaccine and eliciting an emotional connection through personal stories of those impacted by COVID-19.

Conclusion: Specific considerations, such as leveraging the public's trust in healthcare professionals to act as a liaison between Public Health and the Canadian public to communicate the benefits of the vaccine against COVID-19 and its variants, may help reduce COVID-19 vaccine hesitancy.

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Keywords: vaccine hesitancy, social media, health communication, COVID-19, vaccines

Introduction

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) is an infectious respiratory pathogen responsible for coronavirus disease 2019 (COVID-19) (1). To slow the spread of COVID-19, many regions within Canada instituted indoor mask use and physical distancing. On March 23, 2020, Prime Minister Justin Trudeau urged Canadians to "go home and stay home" and adhere to physical distancing recommendations. Following increasing evidence of asymptomatic spread, on April 6, 2020, Canada's Chief Public Health Officer recommended Canadians wear non-medical masks (2). Even with these mitigation measures, as of September 2021 there were more than 27,000 deaths in Canada—and over 4.6 million deaths worldwide (3,4). Given that vaccines are the most successful and important public health intervention to prevent spread of infectious disease (5), it has become well accepted that a COVID-19 vaccine is the best way to develop both personal and population-level immunity (6,7). In September 2020, the expedited process of approving COVID-19 vaccines was authorized in Canada (8), which allowed for approval of Pfizer-BioNTech, Moderna, AstraZeneca and Janssen vaccines between the end of 2020 and early 2021 (9).

Research has shown that public confidence in vaccines has remained low in recent years and continues to be a dynamic and complex issue (10–12). Lack of vaccine confidence has resulted in vaccine hesitancy, identified by the World Health Organization as one of the top 10 threats to global health (13). Vaccine hesitancy is defined as refusal or delay in acceptance of an available vaccine and is context specific, meaning that an individual may refuse some vaccines and accept others (14). Digital communication technology, such as social media (SM), has been found to propagate the spread of vaccine-related misinformation (15) that contributes to vaccine hesitancy (16).

Opportunities exist to leverage SM use for public health initiatives that counter vaccine misinformation and increase vaccination rates (16,17). This is an important consideration as the Canadian Community Health Survey shows 75% of Canadians aged 12 years and older would be somewhat or very likely to get the COVID-19 vaccine (18). Results from Angus Reid Institute showed that 48% of Canadians said that they would receive a COVID-19 vaccine when available, 38% would eventually but not immediately, 14% would not and 7% were unsure (19). These attitudes towards COVID-19 vaccinations are important to consider given a large proportion of the population needs to be vaccinated to achieve herd immunity (20).

To create successful public health initiatives that counter vaccine hesitancy and promote vaccine acceptance, it is necessary to gain an understanding of the beliefs, attitudes and subjective risk perceptions of the population (21). A recent study examining COVID-19 vaccine intention found that perceived benefits and barriers played a role in intention to receive the COVID-19 vaccine (22). Neubaum and Krämern stated that SM may serve as "a window to the public", providing insight into public perception and opinion. Research has shown that SM users may feel empowered to share their thoughts and opinions when they see posts espousing similar beliefs (23,24) and when they can do so anonymously (25). These online comments act as an accurate and reliable source of information on public attitudes and perceptions that surface during a health crisis (26). For example, a recent study used English-language Twitter posts to examine public perceptions of COVID-19 social distancing measures (27) and found their results reflected the attitudes and opinions of a large United States public opinion poll taken during the same timeframe (28,29). Taken together, SM could be used to gain an understanding of perspectives of the Canadian population towards public health issues, including perceptions, beliefs, attitudes and intentions toward receiving a COVID-19 vaccine.

In recent months, perceptions and attitudes toward taking a COVID-19 vaccine (30–32) have been investigated, and a growing body of research has focused on those perceptions and attitudes expressed on SM (33–36). To better inform public health recommendations to counter vaccine hesitancy in Canada, further research that examines SM discourse on Twitter and Facebook in response to Canadian news organizations' COVID-19 vaccine reporting may help provide a more comprehensive understanding of the attitudes, beliefs and intentions toward taking a COVID-19 vaccine among Canadians.

Methods

Data collection

Six popular Canadian national news organizations were selected; specifically, Global News, Canadian Broadcasting Corporation (CBC), Canadian Television Network (CTV), The Globe and Mail, Maclean's and The National Post to identify the perceptions, attitudes, beliefs and intentions of Canadian news organizations' SM commenters toward taking a COVID-19 vaccine. These are the predominant national news content providers in Canada that report the news through television broadcast (Global News, CBC, CTV) or print (The Globe and Mail, Maclean's, The National Post), as well as online. Compared with a quantitative analysis, which provides information on vaccine of hesitancy patterns among populations, a qualitative approach offers a deeper analysis of the socio-cultural aspects of vaccine hesitancy (37). Thus, a qualitative approach was selected to allow for an in-depth exploration into the nuances and complexities of vaccine hesitancy among Canadians.

Social media posts from the Twitter and Facebook accounts of the six Canadian news organizations listed above were monitored for when a COVID-19 vaccine-related article was shared on their Twitter and Facebook account. Twitter and Facebook were chosen because comments on these platforms have been used to answer vaccine hesitancy research questions in previous studies (33,38,39) and both platforms allow news organizations to link back to articles on their website. All data were gathered between July and September 2020, and only English posts were collected for analysis. Each SM post included a link to their respective news article and often included a comment inviting SM engagement. These news organizations were selected because they are nationally representative organizations with credible reporting practices and represent a range in political leanings. All commenters are users of SM with accounts on Twitter and/or Facebook. Authors looked for news articles that included information on development or procurement of COVID-19 vaccines or reported on vaccination survey results. Seven days after the COVID-19 related news article was shared on the organizations' SM account, all posted comments were collected. A seven-day timeframe was sufficient to collect SM comments made on that article, as few comments were posted after this time.

A total of six articles (one article per new organization posted on both Twitter and Facebook) and 4,095 comments were collected for analysis. The data were then scanned for spam, which was defined as insults toward other commenters, comments that were not on the topic of the COVID-19 vaccine, comments that were not legible (e.g. used only characters) and images (e.g.

GIFS). A total of 364 posts that included spam and irrelevant comments were deleted and images that contained text, if related to COVID-19, were transcribed verbatim. Once data cleaning was complete, a total of 3,731 posts remained for analysis. The number of posts per news organization and links to each original article are shown in **Table 1**.

Table 1: Total number of combined Twitter and Facebook posts for each news organization used in analysis and links to each news organizations' original COVID-19 vaccine related article posted on their respective social media accounts

News organization	Number of posts	Link to original article
National Post	308	https://nationalpost.com/health/which-canadians-get-the-covid-19-vaccine-first-experts-are-struggling-to-decide
Maclean's	642	https://www.macleans.ca/society/health/how-anti-vaxxers-could-disrupt-the-cure-for-the-covid-19-pandemic/
The Globe and Mail	70	https://www.theglobeandmail.com/canada/article-moderna-inc-says-its-covid-19-vaccine-shows-positive-results-among/
Global News	745	https://globalnews.ca/news/7251593/canada-pfizer-coronavirus-vaccine/
CBC	498	https://www.cbc.ca/news/world/coronavirus-covid19-world-sept4-1.5712020
CTV	1,468	https://www.ctvnews.ca/health/coronavirus/feds-sign-deals-with-novavax-and-johnson-johnson-to-secure-millions-of-vaccine-doses-1.5085911

Abbreviations: CBC, Canadian Broadcasting Corporation; COVID-19, coronavirus disease 2019; CTV, Canadian Television Network

This research study relied exclusively on publicly available data with some sources as anonymous or unidentifiable; therefore, ethical approval was not required. This is consistent with similar Canadian-based research using publicly available SM content (33).

Analysis

Original posts from each news organizations' Twitter and Facebook account, along with accompanying comments, were imported into NVivo-12 (QSR International, 2019). Using Clarke and Braun (40) as a guide, each of this study's researchers conducted thematic analysis to identify themes as the unit of analysis. Analysis involved each researcher independently coding each comment and reply over a 10-week period. Researchers met bi-weekly to examine and discuss differences in the codes, which became the building blocks of the themes (40). Based on previous vaccine hesitancy literature, perceptions, attitudes, beliefs and intentions were used as sensitizing concepts to approach qualitative analysis. Sensitizing concepts refer to general ideas that act as starting points for researchers approaching a qualitative research question (41). Using these sensitizing concepts as guide for analysis, the authors then used inductive analysis to allow themes and patterns to emerge from the data (41). All three researchers noticed similar themes among the data, and once coding was complete, all researchers met to finalize the list of agreed themes and subthemes.

Results

Four themes emerged from comments gathered in response to news organizations' SM posts. For each theme, subthemes were also identified. Most SM comments and replies expressed negative attitudes and opinions toward the COVID-19 vaccine, while some expressed positive beliefs and attitudes. Each theme is described in the following pages, where illustrative quotes were used to contextualize themes. A summary of themes with supplementary quotes can be found in **Table 2**.

Theme 1: COVID-19 vaccine safety and efficacy concerns

Theme 1 captured concerns about perceived factors that may influence the safety and efficacy of the vaccine including political pressures, development speed and testing, ingredients and potential immune-escaping variants.

Political pressures influencing vaccine production: Concerns were expressed around the perceived influence of political pressures rushing vaccine production. For example, one commenter noted "Would I get the Russian vaccine or Trump's vaccine to win an election[?] .. not a chance." - CTV, Twitter. Another commenter, referring to the influence of politicians wrote, "Medical experts are dictated what to do by politicians. Trust them at your peril" - Globe and Mail, Facebook.

Others first to prove safety: A common concern referred to safety of vaccine and the belief that they lacked adequate testing. Many commenters remarked that politicians should receive the vaccine first to prove its safety: "I want the whole House of Commons, the Senate, the Governor-General and a special vaccine for the Prime Minister! Then we wait a month and see what happens!" - CTV, Facebook. Another wrote, "I will let the masses be the control group and see what happens. It may be good or not. Time and trial will tell" - CBC, Facebook.

Rushed vaccine: Many commenters expressed concern about the short timeframe for COVID-19 vaccine development. One commenter who characterized themselves as not being an "anti-vaxxer", a word that describes someone who is opposed to vaccines, noted, "There will be a lot of people like me who are not anti-vaxxers but will refuse this until a reasonable amount of time for proper testing and data goes by." - National Post, Facebook.

Table 2: Supplementary quotes from social media commenters in response to Canadian news organizations' COVID-19 vaccine related Twitter and Facebook posts organized by theme and subtheme

Theme	Subtheme	Quote
COVID-19 vaccine safety and efficacy concerns	Political pressures influencing vaccine production	"These scientists are under a tremendous amount of pressure for governments to push though and get a vaccine up and running and that's how we end up with oppsys" - CTV, Facebook "Would you take a vaccine that did not undergo full trials? DJT [Donald J Trump] is proposing forgoing phase 3 trials in order to rush a vaccine to production" - CBC, Twitter
	Others first to prove safety	"I'll wait for all the heroes to go first, if they survive maybe" - CTV, Twitter "Nope. Not until I see what happens to all the eager beavers. I'm no guinea pig" - CTV, Twitter "The yes voters can line up to be guinea pigs while the intelligent people wait and see what happens." - Global News, Twitter "I think all our lovely politicians should be the first to get it and we can all wait 6 months to see how that turns out." - CTV, Facebook
	Rushed vaccine	"I wont be a Guinea pig. I'll wait 5-10 years for a long term study to be peer reviewed and make sure the side effects of the vaccine arent worse than the effort it takes to avoid covid." - CBC, Facebook "Anybody dumb enough to get injected by a rushed and undertested vaccine deserves every side effect from it." - CTV, Facebook "Nope...and I am not anti vaxx.....I am anti being a guinea pig for a rushed vaccine that hasn't been properly tested" - CTV, Facebook "I am not against vaccines but I will not be getting this. It's just too fast and not tested enough for me to want to take this." - Maclean's, Facebook "You do know it takes roughly 10 years to develop and properly test a vaccine right? Go ahead and trust something developed in 4 months with zero long term effects results but if you value yourself you'd wait until you had irrefutable evidence that this vaccine is 100% safe with only a SMALL chance of complications taking place like every other rigorously tested and proven to be safe vaccine." - National Post, Facebook
	Ingredient concern	"go ahead and have and have mine too but don't judge others that have no desire to put unknown chemicals in their body" - CTV, Facebook "…check what is in vaccines and what they really do and they don't want chemicals like formaldehyde, mercury and aluminum in their bodies" - Maclean's, Facebook "Read the insert and see what is in it. Fetal DNA. Yes, aborted fetus cells. Toxic chemicals beyond comprehension. You demand a mask for your health and then BLINDLY inject these toxins directly into your bloodstream. RESEARCH what's in them!" - Global News, Twitter
	Vaccine versus variants	"We don't yet know, or at least aren't told the mutation rate of Covid … vaccination may be a frequent undertaking and possibly with no real effect." - National Post, Facebook "covid is already mutating so good luck with that" - CBC, Facebook "Think of how many times the virus will have morphed by the time they actually get the vaccine out..." - CBC, Facebook
Conspiracy theories stemming from mistrust in government and other organizations	General mistrust in government	"I don't trust our government anymore and won't be used as a guinea pig." - Global News, Twitter "Who wants to take a shot in the arm, from a gov. that has had 3 ethics investigations, is so very far from anything resembling "transparency" it should really be criminal. JT [Justin Trudeau] - fancy socks mr. word salad has been sticking it up our Cdn. butts long enough, no don't touch my arm. Clearly you are Not to be trusted." - CTV, Facebook "… Just because the government says it's okay and pushes thru the creation and testing does not make me feel confident about it." - Global News, Facebook "0% trust in the Canadian Healthcare system to provide a safe version of CV19 vaccination." - Global News, Twitter "Scientists can be bought just like politicians. Stop being naive thinking the government wants what's best for us". - CTV, Facebook
	COVID-19 vaccine will alter your DNA	"Do you realize that the new mRNA vaccine which BigPharma is touting as the savior from COVID is in fact altering your DNA? No wonder they put Gates in the forefront to sell it. They're labeling it as The "Software of Life." - Global News, Twitter "Enjoy having your DNA altered for the rest of your life and your children's life." - Global News, Twitter "Why would I take it knowing it was DNA chipped. Meaning changing your genomes and DNA ... Should have been asking why are they are rushing to inject the population with it." - CTV, Facebook
	Microchips and nanotechnology	"I don't want to be microchipped from Bill Gates, it's a mind control device which can simply make you walk off the edge of the flat Earth Face with hand over mouth." - Global News, Twitter "Those of us with a strong immune system will survive just fine without Gatesfromhell vaccine that he has admitted will kill over 700 000 people. You go get yourself microchipped like a cow." - Maclean's, Facebook "There's a huge difference between a chip in a phone or electronic and one in your body! At least you can leave your phone home." - CTV, Facebook

Table 2: Supplementary quotes from social media commenters in response to Canadian news organizations' COVID-19 vaccine related Twitter and Facebook posts organized by theme and subtheme (*continued*)

Theme	Subtheme	Quote
COVID-19 vaccine is unnecessary because the virus is not dangerous	It is just "fear mongering"	"I'm sure we could go back to pre-plandemic life if the media just quit the fear mongering" - CTV, Facebook
		"your fear propaganda is a farce. your mask mandates are a farce. your inflated statistics are a farce." - CTV, Facebook
		"Just some more fear mongering by our ridiculous government have a great day." - CTV, Facebook
	COVID-19 is not that serious	"You had better chance dying of cancer or car fatalities any other health reason on a daily basis then getting infected with COVID or dying from it." - CTV, Facebook
		"Is a vaccine really required for a disease so deadly one has to get tested to see if they have it" - CTV, Facebook
		"my wife and I both had it (we are both immunodeficient) No hospital stay the cough lasted about 3 weeks and we have 0 long term affects." - CTV, Facebook
		"A vaccine for a virus with a 0.03% mortality rate? I'll pass thanks!" - The Globe and Mail, Facebook
	Strong immune systems and a healthy lifestyle is sufficient to beat COVID-19	"I'm not immune compromised, I'm not a senior, I'm healthy, and every flu I've had, my bodies own defenses have overcome it in the normal anticipated time of infection." - Global News, Facebook
		"just eat, sleep and exercise and you will be fine. if everyone did that then 80 percent of the healthcare system wouldn't be needed."- Global News, Facebook
		"I would like to be immune to it with my natural bodies antibodies." - Global News, Facebook
		"Eating healthy: Non processed, non GMO, organic foods, exercise, get a good amount of sleep, take vitamins, get lots of vitamin d from sun, the list goes and on and on of what you can do to stay healthy. I don't need chemicals to keep me healthy. Let the body do its thing and if I catch a cold, flu or covid then i will deal with it." - Global News, Facebook
Trust in COVID-19 vaccines as a safe solution	Trust in science and medical professionals	"I've seen the ingredients, and unlike some people, I don't misinterpret them. Some ingredients might look sketchy to anyone who doesn't understand chemistry." - Global News, Twitter
		"id say testing on over 50,000 people is good enough" - Global News, Facebook
		"no one is going to be distributing an untested vaccine. It may not be possible to test for long-term protection, but it will definitely be tested for both safety and effectiveness." - CTV, Facebook
		"As I said, my risk management plan involves listening to my family doctor, and to my wife who is a retired infection control nurse. Those two women have never led me astray. I wish you good luck with your alternate plan." - Maclean's, Facebook
		"The reason it can be made so fast is because it is a virus we are familiar with. Also not sure if you realize this but research and technology has progressed" - CBC, Facebook
	Concern about long term effects of COVID-19	"The issue is not only the mortality of covid, but the seriousness of the illness and the long term effects. But for now, you may not die from covid, but you may die waiting for help in an overcrowded hospital full of covid patients." - Globe and Mail, Facebook
		"almost everyone interviewed in media, old and young, who have had it are saying they're still not feeling 100% ... some have memory loss, loss of energy etc." - CTV, Facebook
		"Healthy people can still suffer permanent damage and death" - Global News, Twitter
	Intent to get the COVID-19 vaccine to protect others and return to "normal"	"Thank you for one of the few voices of reason in a crowd of howling anti-vaxxers. As someone with loved ones with health concerns, I will be first in line to get my shot." - CTV, Facebook
		"Maybe if everyone got vaccinated, used masks, and social distance then maybe life would get back to normal 10 times faster than predicted." - CTV, Facebook

Abbreviations: CBC, Canadian Broadcasting Corporation; COVID-19, coronavirus disease 2019; CTV, Canadian Television Network

Ingredient concern: Safety concerns related to the ingredients used to develop the COVID-19 vaccine. "You go ahead fill your veins with fetus tissue and mercy and formaldehyde and then get back to ya and see how great you feel!" - Global News, Facebook.

Vaccine versus variants: Commenters were concerned about vaccine efficacy once the COVID-19 virus mutates. One commenter wrote, "There is the distinct possibility that covid mutates and renders any vaccine useless" - Maclean's, Facebook, while another noted, "Think of how many times the virus will have morphed by the time they actually get the vaccine out...". - CBC, Facebook.

Theme 2: Conspiracy theories stemming from mistrust in government and other organizations

Theme 2 characterized the conspiracy theories, including microchips and changes to DNA, expressed on SM rooted in a general mistrust of government and organizations involved in COVID-19 vaccine development.

General mistrust in government: All six news organizations' article posts on SM contained comments pointing toward mistrust of foreign and domestic government and health organizations. One commenter when speaking about the government wrote, "No one iota of trust. I am not a guinea pig for government vaccine tests" - Global News, Twitter.

The COVID-19 vaccine will alter DNA: Comments about the vaccine altering DNA were common on all news organizations' SM platforms: "Insane! Do these people have any idea what this vaccine entails?! It will literally alter your DNA. Forever." - Global News, Facebook. Another commenter wrote, "I don't need nor do I want anyone altering my DNA" - Global, News, Twitter.

Microchips and nanotechnology: Discourse focused on microchips and nanotechnology was common. One commenter wrote, "I dont wanna get chipped" - CTV, Facebook, while another responded, "Bill Gates can keep his nanobot juice, lol." - Global News, Facebook.

Theme 3: A COVID-19 vaccine is unnecessary because the virus is not dangerous

Theme 3 captured the level of concern related to the perceived seriousness of becoming infected with COVID-19 expressed on SM. Commenters felt that severity was being overexaggerated and a healthy immune system was sufficient to overcome the virus.

It's just "fear mongering": Many commenters felt the virus is not as serious as the media was reporting. In response to a question posed by a news agency asking whether people will get the vaccine, one commenter responded, "Just some more fear mongering by our ridiculous government". - CTV, Facebook.

COVID-19 is not that serious: Many commenters noted that a COVID-19 vaccine was unnecessary because the virus was not dangerous. For example, "It's already hit my house, both my wife and I at very high risk, no hospital for either of us and yet here we are!!" - CTV, Facebook, while another commenter wrote, "I'm more likely to die walking down my stairs than die of Covid." - Global News, Twitter.

Strong immune systems and a healthy lifestyle is sufficient to beat COVID-19: Commenters discussed how being in good health was sufficient to overcome the virus, "Maybe it's the world's way of weeding out the weak. Most have underlying conditions and we are in perfect health so covid is not a concern for us." - CBC, Facebook. Another commenter wrote, "eat healthy vitamins that's the best vaccine we can get it". - CTV, Facebook.

Theme 4: Trust in COVID-19 vaccines as a safe solution

A minority of commenters expressed confidence in COVID-19 vaccines to prevent infection. Those with confidence in the vaccine conveyed trust in science and their healthcare professional, expressed concerns about potential long-term COVID-19 effects and felt that the vaccine was necessary to return to normal.

Trust in science and medical professionals: Commenters expressed trust in the science behind the vaccines: "If health Canada approves a vaccine, I'll be in the first available line" - CTV, Twitter. Another commenter wrote, "Sign me up, Surprisingly I trust science and the medical safeguards in place. I know completely unheard of." - National Post, Facebook.

Other commenters expressed trust in medical professionals: "If my Dr. Recommends it I would." - Global News, Twitter. Another wrote, "I will follow my doctors advice as I dont have a spleen." - Global News, Twitter.

Concern about long-term effects of COVID-19: Several commenters noted concern about potential long-term effects of being infected with the COVID-19 virus. One commenter wrote, "the issue is not just those who have died but those who have survived, what they went through and the longer lasting effects..." - CTV, Facebook. Another wrote, "I'm more then willing to take it, the long-term effects from getting Covid are the driving force for me" - CTV, Facebook.

Intent to get the COVID-19 vaccine to protect others and return to "normal": Commenters expressed intention to get the COVID-19 vaccine so that they are able to return to their normal life, "Will be first in line so we can go back to normal" - CTV, Facebook. Another wrote, "As soon as it's available! Definitely plan on doing my part to protect the vulnerable" - Global News, Facebook.

In contrast, those expressing intention to receive the COVID-19 vaccine were met with ridicule. Comments such as "Yup…all the scared sheeple will be lining up dutifully and shaming anyone who resists" - CBC, Twitter, were common.

Discussion

The aim of this study was to examine SM discourse on Canadian news organizations' SM accounts in response to posted articles reporting on the COVID-19 vaccine. Comments on article posts were analyzed to identify perceptions, attitudes, beliefs, and intentions toward taking a COVID-19 vaccine. Our analysis identified four themes and a number of sub-themes.

Comments expressing concern about safety and efficacy of a COVID-19 vaccine were common. This is consistent with previous research that examined reasons for vaccine hesitancy, with safety and efficacy concerns as the main driver for vaccine hesitancy (42,43). The common concern about a "rushed" vaccine is not unique to COVID-19. Research examining responses to the H1N1 vaccine found that people were concerned about seemingly rushed vaccine development (44). These findings are consistent with our analysis and are troubling as research has found that COVID-19 vaccine acceptance is strongly related to perceived safety (45).

Commenters were concerned about ingredients in the COVID-19 vaccine. These findings are consistent with previous research by Björkman and Sanner (46) that examined the experiences and beliefs of taking the H1N1 vaccine in Sweden. This study determined that participants were concerned about putting "unknown substances" contained within the vaccine into their body (46). Taken together, it appears a lack of understanding regarding vaccine contents has been a consistent barrier to vaccine uptake.

Social media commenters were concerned about COVID-19 viral mutations rendering the vaccine ineffective against the virus. Research has shown that speed of vaccination can offset the harm of more easily transmissible variants (47). Thus, Public Health messaging that addresses concerns about COVID-19 viral variants and encourages uptake of the vaccine is needed.

Our analysis found that a reason for supporting a COVID-19 vaccine was concern about potential long-term effects of the virus. This is consistent with previous research that identified that perceptions of disease severity were associated with willingness to receive a COVID-19 vaccine (43,48,49). One suggestion to increase vaccine uptake could be the sharing of local data through clear infographics to illustrate the success of the COVID-19 vaccine for those who been vaccinated. This may positively influence those who are hesitant on efficacy grounds, with messaging emphasis shifted toward the risk of developing long-haul COVID-19 symptoms. Additionally, it is clear from our results and previous research (43,48,50) that healthcare providers are effective participants in vaccine communication, as several commenters mentioned that they would get the vaccine if it was recommended by their doctor.

Limitations

Study limitations should be considered when interpreting results. First, it is likely that readers who comment on vaccine-related posts have strong negative feelings toward the vaccine. Research has shown that anti-vaccine content on SM leads to more user engagement than pro-vaccine content (16). Second, we did not investigate each commenter to identify non-human accounts, specifically "bots". Bots are defined as automated accounts that can be designed to spread misinformation and anti-vaccination content (51). Yuan *et al*. found 1.45% of accounts participating in vaccine discourse on SM were bots (52). Third, only English posts were included in analysis and therefore not representative of the broader non-English speaking population. Although data were independently coded by each of the three researchers to reduce bias (53), we only used social media posts and therefore could not triangulate findings from multiple sources of information. Finally, we could not collect demographic information from commenters and therefore could not make conclusions about generalizability of results to the Canadian population. Future research in this area should consider multiple methods of data collection to test validity through analysis of information from several sources, examine SM discourse in languages other than English and on additional SM platforms.

Future directions

Results from this study can help inform Canadian Public Health COVID-19 vaccine messaging. Previous research has shown that Public Health communications can positively impact vaccine intention (22), and themes found in this study are consistent with previous research that aimed to identify effective vaccine messaging. Indeed, increasing public knowledge of COVID-19 disease severity and vaccine safety is imperative since these were primary concerns from commenters in this study and from participants in previous research (42,49,54,55). Further, our results are consistent with published literature (43,48,50) demonstrating healthcare providers can be an effective mode for reliable vaccine communications. Taken together, successful efforts can be made toward improving vaccine messaging on SM to reduce vaccine hesitancy.

A renewed public information drive is required to promote public urgency in vaccination as an important tool in fighting COVID-19 and its variants. Our analysis points to key recommendations that may help increase vaccine uptake and decrease hesitancy. This includes the following: 1) Public Health messaging focused on increasing the public's understanding of COVID-19 vaccine contents; 2) leveraging the public's trust in healthcare professionals to act as a liaison between Public Health and the Canadian public to communicate benefits of the vaccine against COVID-19 and its variants; 3) clear infographics championed by Public Health that highlight benefits of the vaccine for those who have received it; and 4) sharing easily understood, poignant stories of local community members experiencing long-COVID symptoms, which may illicit an emotional connection.

Conclusion

An analysis of COVID-19 vaccine discourse on SM identified four themes related to the perceptions, attitudes, beliefs, and intentions toward taking a COVID-19 vaccine. These included both negative (concerns about COVID-19 vaccine necessity, safety and efficacy) and positive (trust in COVID-19 vaccines as a safe solution) themes. Based on these findings, specific recommendations to reduce vaccine hesitancy were developed.

Authors' statement

LT — Led the project, conceptualization and study design, methodology, data collection, formal analysis, and interpretation of data, writing, editing, and creating final draft
SD — Conceptualization and study design, methodology, data collection, formal analysis, and interpretation of data, writing, editing, and creating final draft
AL — Methodology, formal analysis and interpretation of data, writing, editing, and creating final draft

All authors have reviewed and approved the final article.

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Competing interests

The authors declare no conflict of interest.

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The PRONTO study: Clinical performance of ID NOW in individuals with compatible SARS-CoV-2 symptoms in walk-in centres—accelerated turnaround time for contact tracing

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Abstract

Background: This PRONTO study investigated the clinical performance of the Abbott ID NOW™ (IDN) COVID-19 diagnostic assay used at point of care and its impact on turnaround time for divulgation of test results.

Methods: Prospective study conducted from December 2020 to February 2021 in acute symptomatic participants presenting in three walk-in centres in the province of Québec.

Results: Valid paired samples were obtained from 2,372 participants. A positive result on either the IDN or the standard-of-care nucleic acid amplification test (SOC-NAAT) was obtained in 423 participants (prevalence of 17.8%). Overall sensitivity of IDN and SOC-NAAT were 96.4% (95% CI: 94.2–98.0%) and 99.1% (95% CI: 97.6–99.8), respectively; negative predictive values were 99.2% (95% CI: 98.7–99.6%) and 99.8% (95% CI: 99.5–100%), respectively. Turnaround time for positive results was significantly faster on IDN.

Conclusion: In our experience, IDN use in symptomatic individuals in walk-in centres is a reliable sensitive alternative to SOC-NAAT without the need for subsequent confirmation of negative results. Such deployment can accelerate contact tracing, reduce the burden on laboratories and increase access to testing.

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Keywords: COVID-19, SARS-CoV-2, nucleic acid amplification tests, rapid tests, Abbott ID NOW, sensitivity and specificity, predictive value, diagnostic performance, point-of-care testing, Canada

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Introduction

Currently, the most reliable methodologies for coronavirus disease 2019 (COVID-19) testing are standard laboratory-based nucleic acid amplification tests (NAAT). However, over the first waves of the pandemic, reagent shortages and high demand have challenged our public health capacity and reactivity (1–4). The long turnaround time (TAT) required to produce a test result has also compromised search and contact tracing strategies (5–7). Stand alone rapid tests in specific settings are expected to accelerate case and contact tracing, along with improving public health actions (8–10).

The Abbott ID NOW™ (IDN) COVID-19 assay, an isothermal NAAT targeting a RdRp segment of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was granted Health Canada emergency use authorization on September 30, 2020. It is authorized as a lab-based and point-of-care diagnostic assay for the detection of SARS-CoV-2 in individuals with COVID-19 symptoms for fewer than or equal to seven days at time of testing. Early published studies established a lower analytical sensitivity compared with many laboratory-based NAAT assays (11–15). According to the product insert, negative results are to be treated as presumptive and be confirmed with a cleared NAAT. The Canadian Public Health Laboratory Network and the Canadian Society of Clinical Chemist subsequently recommended certain clinical use scenarios to balance expected limited sensitivity with other considerations (16).

Published literature demonstrated that the clinical sensitivity of IDN was linked to corresponding viral loads, with false negative results tending to occur when the standard laboratory-based NAAT cycle thresholds (Ct) are 32 or higher, reflecting lower viral loads (12,13,17). As shown by others, the highest viral loads were found in symptomatic participants presenting in community walk-in centres (9–11). The present study aimed to assess whether IDN could be used as a reliable stand-alone test (without subsequent confirmation) as a means to intervene more quickly on transmission chains, relieve laboratory human and material resources and give more autonomy to front-line healthcare providers. As such, we are reporting the agreement and clinical performance of the IDN, compared to a standard-of-care NAAT (SOC-NAAT) assay, among prospectively recruited symptomatic individuals presenting in community walk-in centres in the province of Québec, Canada.

Methods

In December 2020, IDN instruments were implemented in three walk-in centres in the province of Québec. Volunteer participants were asked to confirm that symptom onset was fewer than or equal to seven days prior to testing and to provide two samples simultaneously, as detailed in **Table 1**.

The oropharyngeal and bilateral nasal swab (OBNS) for the IDN assay was collected with the foam swab provided with the Abbott ID NOW COVID-19 kit as follows: after swabbing the posterior pharynx, tonsils and other inflamed areas for a few seconds each, the swab was inserted in one nostril until a resistance was met at the level of the turbinates (approximatively 2 cm), rotated five times against the nasal wall and slowly removed from the nostril; the same swab was then used for the other nostril. The OBNS for IDN was collected after the oral and nasopharyngeal swab (ONPS) for SOC-NAAT in Québec City and Montréal (18), but performed prior to the gargle for SOC-NAAT in Lévis (19), since the gargle procedure could dilute any virus present when swabbing for IDN.

The IDN test was performed on-site, within one hour of collection, by professionals from diverse training and experience backgrounds who were trained by our teams on using the IDN instrument as per the package insert.

Table 1: Characteristics of the participating centres: Type of clinic, sampling and testing methodologies

Characteristics	Québec City and Montréal	Lévis
Type of centre	Walk-in clinic	Drive-thru clinic[a]
SOC-NAAT sampling	ONPS	Gargle ONPS (when gargle not feasible)
SOC-NAAT method	Laboratory-developed PCR	Allplex™ 2019-nCoV (Seegene) direct PCR
Sampling sequence	SOC-NAAT followed by IDN	IDN followed by SOC-NAAT
IDN sampling	OBNS	OBNS

Abbreviations: IDN, ID NOW™; OBNS, oropharyngeal and bilateral nasal swab; ONPS, oral and nasopharyngeal swab; PCR, polymerase chain reaction; SOC-NAAT, standard of care-nucleic acid amplification testing
[a] For text simplification, all three centres were considered as walk-in clinics

The SOC-NAAT in Montréal (Hôpital Maisonneuve-Rosemont; HMR) and Québec City (CHU de Québec) was a real-time polymerase chain reaction (PCR) assay targeting the structural protein envelope *E* gene (18,20). Inactivation and thermal lysis, rather than chemical extraction, were performed prior to PCR testing, as previously described (18). The SOC-NAAT in Lévis (Centre intégré de santé et de services sociaux [CISSS] de Chaudière-Appalaches) was based on Seegene Allplex™ technology as previously described (19).

No personal data were collected outside of the information available on the standard COVID-19 laboratory form (gender, age, duration of symptoms, COVID-19 contact history). The duration of symptoms and contact history, combined with supplemental NAAT when applicable, were used to classify infection stages of participants for whom discordant results were obtained. Acute infection was defined as at least having one symptom among fever, cough, runny nose, dyspnea, sore throat, anosmia and ageusia, or a combination of two of the following: headache, fatigue, muscle pain, anorexia, nausea or vomiting, abdominal cramps or diarrhea within seven days of onset. When the collected data revealed misclassification, erroneous data collected by staff or by participant mistake, the case remained included in the study since representing a real-life situation.

For each study site, TAT was defined as the time between sample collection and the availability of the laboratory report for concordantly positive pairs (both the IDN and the SOC-NAAT results were reported). In Lévis, the time between sample collection and completion of public health questionnaire with the case and household contacts was also calculated. The TAT for negative results was not monitored since negative IDN results were not reported during the study period.

This PRONTO study was undertaken in the midst of the second wave of the COVID-19 in Québec, with thousands of samples being received on a daily basis. There was a context of emergency (with public, administrative and media pressure) to implement rapid testing. Formal Ethical Review Board approval was lifted since the study was mandated by the *directeur national de santé publique* as part of the Public Health response during the sanitary emergency state. Explicit verbal consent was obtained from all participants after receiving a verbal description of the project.

Statistical analysis

Samples producing invalid results in either arm were excluded from the calculations.

Data were analyzed using a contingency table. In the absence of a gold standard for SARS-CoV-2 ribonucleic acid (RNA) detection, the reference method used for positive percent agreement and negative percent agreement was the SOC-NAAT. In addition to computing the overall rates of agreement, the level of agreement was assessed using kappa statistics (STATA V16.1). By definition, kappa values above 0.75 indicate excellent agreement, values between 0.40 and 0.75 indicate fair to good agreement, and values below 0.40 represent poor agreement beyond chance (21). To evaluate the clinical sensitivity and negative predictive value of IDN and SOC-NAAT, a participant was considered infected if at least one result from the paired samples was positive, assuming 100% specificity of both assays. The 95% confidence intervals (95% CI) were obtained with STATA V16.1.

Outcomes

Between December 6 and February 22, 2020, paired samples were obtained from 2,395 individuals. After exclusion of 23 pairs associated with an invalid result with either method, the performance analysis was based on 2,372 participants (**Table 2**).

Table 2: Participant characteristics and number of valid pairs included (N=2,395)

Participant characteristics	Québec City		Lévis		Montréal		Total	
	n	%	n	%	n	%	n	%
Symptomatic participants recruited	1,246	N/A	790	N/A	359	N/A	2,395	N/A
Invalid results	12	1.0	9	1.1	2	0.6	23[a]	1.0
Valid paired samples	**1,234**	**99.0**	**781**	**98.9**	**357**	**99.4**	**2,372**	**99.0**
Male gender	544	44.1	370	47.4	154	43.1	1,068	45.0
Mean age	40	N/A	32	N/A	38	N/A	37	N/A
Age range (years)	1–88	N/A	1–83	N/A	1–80	N/A	1–88	N/A
Younger than 18 years of age	118	9.6	109	14.0	33	9.2	260	11.0

Abbreviation: N/A, not applicable
[a] Among the 23 excluded pairs, 22 invalid results were obtained with Abbott ID NOW™ and one with standard-of-care nucleic acid amplification test

As shown in **Table 3**, a total of 423 participants (17.8%) were considered infected (at least one positive result by IDN or SOC-NAAT). Positive concordant results were obtained on 404 pairs (95.5%); among the 19 discordant pairs, four were positive with IDN only and 15 with SOC-NAAT only. Agreement was excellent, as reflected by a kappa coefficient value of 0.97. Overall, IDN sensitivity and negative predictive value were respectively estimated at 96.4% (95% CI 94.2–98.0) and 99.2% (95% CI 98.7–99.6), with little (not statistically significant) variation across centres (**Table 4**).

Table 3: Prevalence of SARS-CoV-2 infection and distribution of Abbott ID NOW™ and standard-of-care nucleic acid amplification test results in symptomatic individuals (n=2,372)

Location	Prevalence[a]		Results		
	n/N	%	IDN	SOC-NAAT	
				POS	NEG
Québec City	193/1,234	15.6	POS	187	2
			NEG	4	1,041
Lévis	114/781	14.6	POS	109	1
			NEG	4	667
Montréal	116/357	32.5	POS	108	1
			NEG	7	241
Total	423/2,372	17.8	POS	404	4
			NEG	15	1,949

Abbreviations: IDN, ID NOW™; NEG, negative; POS, positive; SOC-NAAT, standard of care-nucleic acid amplification testing
[a] A participant was considered infected if at least one result from the paired samples was positive, assuming 100% specificity of IDN and SOC-NAAT

Characteristics of the 19 participants for whom discordant results were obtained are presented in **Table 5**. For the 15 negative IDN, the mean Ct value of the corresponding positive SOC-NAAT was 33.5 (range 30.9–35.0). The mean Ct values for the concordantly positive pairs, available for the Québec City site (26.0) and the Montréal site (23.5), were clearly lower, reflecting a higher viral load. Among the 15 participants for whom the discordant profile was SOC-NAAT positive/IDN negative, two were asymptomatic, four were considered as late presentation and nine as acutely infected. Among the four participants for whom the discordant profile was SOC-NAAT negative/IDN positive, two had an acute infection and two could not be staged nor confirmed by supplementary testing.

The TAT between sampling and availability of laboratory report of positive results was on average 20.1 hours for SOC-NAAT and 1.2 hours for IDN. In Lévis, TAT between sampling and end of public health tracing was on average 36.0 hours for the symptomatic individuals who either had SOC-NAAT positive/IDN negative results or did not participate in this study but were assessed at the same drive-through clinic during the same period, and for whom testing was performed by SOC-NAAT

Table 4: Agreement between Abbott ID NOW™ and standard-of-care nucleic acid amplification testing results and clinical performance (n=2,372)

Test	Statistics	Assessment center			
		Québec City	Lévis	Montréal	Total
Agreement					
PPA[a]	%	98.9	99.1	99.1	99.0
	95% CI	96.2–99.9	95.0–100	95.0–100	97.5–99.7
NPA[a]	%	99.6	99.4	97.2	99.2
	95% CI	99.0–100	98.5–99.8	94.3–98.9	98.7–99.6
ORA	%	99.5	99.4	97.8	99.2
	95% CI	98.9–99.8	98.5–99.8	95.6–99.0	98.8–99.5
Cohen's kappa	K	0.98	0.97	0.95	0.97
	95% CI	0.97–1.00	0.95–1.00	0.91–0.98	0.96–0.98
Clinical performance[b]					
IDN sensitivity	%	97.9	96.5	94.0	96.4
	95% CI	94.8–99.4	91.3–99.0	88.0–97.5	94.2–98.0
SOC-NAAT sensitivity	%	99.0	99.1	99.1	99.1
	95% CI	96.3–99.9	95.2–100	95.3–100	97.6–99.7
IDN NPV	%	99.6	99.4	97.1	99.2
	95% CI	99.0–99.9	98.5–99.8	94.1–98.8	98.7–99.6
SOC-NAAT NPV	%	99.8	99.9	99.6	99.8
	95% CI	99.3–100	99.2–100	97.7–100	99.5–100

Abbreviations: CI, Confidence Interval; IDN, ID NOW™; NPA, negative percent agreement; NPV, negative predictive value; ORA, overall rates of agreement; PPA, positive percent agreement; SOC-NAAT, standard of care-nucleic acid amplification test

[a] PPA and NPA were computed by considering the SOC-NAAT as the reference method

[b] A participant was considered infected if at least one result from the paired samples was positive, assuming 100% specificity of IDN and SOC-NAAT

Table 5: Laboratory and clinical information of participants in whom discrepant results were obtained (n=19)

Assessment center	SOC-NAAT[a] Ct value	Symptoms duration[b,c]	Contact with a known case[b]	Supplementary testing[d]	Clinical stage
IDN negative and SOC-NAAT positive (IDN false negative), n=15					
Québec City	34.2	Symptoms resolved 6 days earlier	Unknown	Initial SOC-NAAT sample retested after chemical extraction: positive result with Ct value of 33.4 Resampled 72 hours later and tested by IDN and SOC-NAAT with a Ct value of 35	Late presentation[e] (post-symptomatic)
	34.8	N/A	Yes, but not detailed	Initial SOC-NAAT sample retested after chemical extraction: positive result with Ct value of 32.4	Asymptomatic
	34.0	Less than 24 hours	Unknown	Initial SOC-NAAT sample retested after chemical extraction: positive result with Ct value of 32.9	Acute presentation
	31.5	More than 7 days	Unknown	ND	Late presentation[e]
Lévis	34.0 (2/3 genes)	N/A	Yes, but not detailed	Resampled 2 days later: negative on IDN and SOC-NAAT IDN swab[f] retested by two other assays[f]: negative results	Asymptomatic
	32.0 (3/3 genes)	2 days	Home	ND	Acute presentation
	30.9 (3/3 genes)	1 day	Workplace	IDN swab[f] retested by two other assays[g]: weakly positive with one assay	Acute presentation
	34.4 (3/3 genes)	1 day	Home	IDN swab[f] retested by two other assays[g]: weakly positive with one assay	Acute presentation

Table 5: Laboratory and clinical information of participants in whom discrepant results were obtained (n=19) (*continued*)

Assessment center	SOC-NAAT[a] Ct value	Symptoms duration[b,c]	Contact with a known case[b]	Supplementary testing[d]	Clinical stage
IDN negative and SOC-NAAT positive (IDN false negative), n=15 (*continued*)					
Montréal	34.2	More than 7 days	Home	ND	Late presentation[e]
	33.5	1 day	Workplace	ND	Acute presentation
	31.6	3 days	Home	ND	Acute presentation
	35.0	7 days	Unknown	ND	Late presentation[e]
	34.2	2 days	No	ND	Acute presentation
	34.9	4 days	Unknown	ND	Acute presentation
	33.3	Less than 24 hours	School	Initial SOC-NAAT sample retested after chemical extraction: positive with Ct value of 33.7	Acute presentation
IDN positive and SOC-NAAT negative (SOC-NAAT false negative), n=4					
Québec City	N/A	2 hours	School	IDN swab[f] tested by NAAT after chemical extraction: positive result with a Ct value of 25.5 Initial SOC-NAAT sample retested after chemical extraction: positive result with a Ct value of 33.8	Acute presentation
		Unknown	Unknown	IDN swab[f] tested by NAAT after chemical extraction: positive result with a Ct value of 30.8 Initial SOC-NAAT sample retested after chemical extraction: positive result with a Ct value of 35.2	Unknown
Lévis		1 day	Unknown	IDN swab[f] tested by two other assays: negative results Initial SOC-NAAT sample retested by two commercial assays[g]: negative results	Acute presentation; possible false-positive IDN
Montréal		5 days	Home	ND	Acute presentation vs. possible false-positive IDN

Abbreviations: Ct, cycle threshold; IDN, ID NOW™; N/A, not applicable; ND, not done; SOC-NAAT, standard of care-nucleic acid amplification test
[a] In Québec City and Montréal, the SOC-NAAT was a laboratory-developed test targeting the *E* gene. In Lévis, the Allplex™ 2019-nCoV assay (Seegene) includes three gene targets (*E*, RdRp and *N*); the Ct values shown are the mean of the two or three positive results obtained
[b] The duration of symptoms before testing and COVID-19 contact history were obtained through the standard routine questionnaire form. Missing information occurs frequently
[c] Some individuals were included in this study based on the assertion that they were symptomatic. The questionnaire form—revised only for discordant pairs—revealed that some participants were asymptomatic. It was decided not to exclude the latter *a posteriori*
[d] The alternate NAAT was the laboratory-developed test preceded by chemical RNA extraction using the NucliSens easyMAG platform (bioMérieux; Saint-Laurent, Canada)
[e] Presentation was considered late when symptoms started more than seven days before sampling as IDN is currently Health Canada-approved for participants tested within the first seven days of symptoms
[f] In Québec City and Lévis, after elution in the IDN Sample Receiver buffer, the swab sample was transported into a dry 15 mL Falcon tube and frozen for possible subsequent testing by NAAT to resolve discrepancies between IDN and SOC-NAAT results or for retesting of the SOC-NAAT sample with a more sensitive laboratory platform
[g] Simplexa COVID-19 (DiaSorin) and FilmArray RP 2.0 (bioMérieux)

(n=283); it was 13.6 hours for the 110 participants for whom the IDN was positive, representing a difference of 22.4 hours (95% CI 18.8–26.1, $p<0.0001$).

Discussion

In this PRONTO study, the clinical performance of IDN was compared to SOC-NAAT among a large number of symptomatic individuals in community-based walk-in centres. Agreement between the two testing strategies was nearly perfect. Although the sensitivity of IDN (96.4%) was slightly lower than for SOC-NAAT (99.1%), the difference was not statistically significant. Very few false negative results were observed in both arms, resulting in excellent negative predictive value of 99.5% and 99.8% for IDN and SOC-NAAT, respectively. Thus, our results differ from earlier studies that demonstrated lower sensitivity (55%–84%) (22,23). Some recent studies suggest a better performance (86%–100%), although the 95% CI in these latter studies were wider, due to a smaller sample size (22–28). This discrepancy in sensitivity might be explained by variation in pre-test probability in the target population (29) and by our optimized swabbing methodology (30). The current study was performed in a group with probable higher viral titers and higher pre-test probability, during a high prevalence wave. A multi-compartment swabbing protocol was also used herein, which included three throat areas and both nostrils, which has been previously shown to be a sensitive alternative to nasopharyngeal swabbing (31). Another possible explanation is that the SOC-NAAT comparators used in our study are associated with lower analytical sensitivity than other commercial NAATs currently used for the detection of SARS-CoV-2 (18).

Indeed, at the Montréal site (data not shown), during the same period, 127 similar individuals (with COVID-19 compatible symptoms) had their ONPS tested by a commercial NAAT: 38 had concordant positive results; 85 had concordant negative results; and four had negative IDN but positive commercial NAAT results (sensitivity of the IDN 90.5%; 95% CI 77.4–97.3).

The discrepant pairs were classified according to their probable clinical stage since later infections with higher Ct values might not represent contagiousness (32–34). We presumed, as a hypothesis for our study, that false negative results would be associated with a lower viral load, with the infected individual being less infectious. Although the timing of the test is important to monitor dynamic viral load, our data confirmed discordant results to be associated with higher Ct, an indirect indicator of viral load (35,36).

The risk of not detecting all cases (or risk of false negative results) can be mitigated by appropriate counselling: automated messages sent with negative results invite people to get retested and seek medical attention if symptoms do not resolve by themselves after 48 hours (37,38). It could also be counterbalanced by the timeliness of the results and the possibility of increasing access to testing by increasing overall laboratory capacity. Although lower IDN sensitivity and missed cases could be deemed obstacles for promoting the technology, we believe otherwise, especially in the context of high vaccination uptake. Clinical sensitivity of a strategy should include analytical sensitivity but also TAT and access to testing. IDN use accelerated contact tracing, and we feel it increased access to testing by offering a less intrusive OBNS sampling and by delocalizing to the point-of-care. In fact, a Québec survey poll showed that half of the eligible population with COVID-19 compatible symptoms did not get tested during the study period (39). Rapid testing or more comfortable sampling methods could represent a valuable solution (18,19).

The optimal approach for the diagnosis of COVID-19 remains under debate. Some experts focus on test sensitivity and neglect the public health and population impacts of accelerated contact tracing (7,8). Although SOC-NAAT processes are now optimised for high testing volume, laboratory resources are profoundly stretched, particularly with the return to "normal" of healthcare activities. An attractive scenario would be to supply IDN directly to first-line clinics, with clear guidance on whom to test with this strategy (for example, symptomatic individuals and close contacts of positive cases). Cost-effective analysis should be undertaken to better guide Canadian public health specialists, microbiologists, administrators and clinicians.

In our study, results were available faster if samples were tested with IDN vs. SOC-NAAT in all assessment centres, with a faster public health inquiry in Lévis for IDN compared to SOC-NAAT. Although representing different indicators, both are proxies for public health intervention, and congruent in showing a net advantage for IDN. Current public health recommendations are that people with COVID-19 symptoms (and their household contacts in certain high-prevalence regions) should self-isolate from the onset of symptoms. However, no interventions have been made to possible contacts until symptomatic participants have a confirmed diagnosis of COVID-19. Without rapid results, public health loses a valuable window of opportunity, particularly if these contacts do not express a typical disease presentation. We can also postulate that adherence to self-isolation is increased when the diagnosis is confirmed.

Strengths and limitations

Among all the similar studies published to date, this PRONTO study has the largest number of participants, even exceeding the total number of participants included in the systematic review by Tu *et al.* (24). Being a multi-site study and performed in a real-life setting (e.g. the personnel performing the IDN testing stemmed from diverse training and experience backgrounds), external validity is increased. We were able to collect comparative data as part of the implementation process in overwhelmed walk-in centres and laboratories. We also aimed to document, in two of the sites, the impact of rapid testing on public health. Although a cause-and-effect relationship between IDN use and the impact on transmission to contacts cannot be established, we postulate that faster tracing will benefit public health containment strategies (9,10).

Our study has certain limitations. First, SOC-NAAT differed between laboratories, although adhered to the same validation panels provided by the provincial Public Health Laboratory. Second, very little participant-level data were collected from participating institutions. As such, IDN could not be correlated with the indications for testing, the appropriateness of the test, and the clinical evolution of participants with positive test results. Third, differences in practices within and between walk-in centres (for example different personnel, rapidly changing recommendations over time) may represent confounding variables; for example, by including some asymptomatic participants. Fourth, our diagnostic definition (at least one positive result from the paired samples), which implies 100% specificity of both assays, may have lead to slight overestimation of the sensitivity for both assays. While false positive IDN results are considered unlikely (28) compared with the well described false positive laboratory PCR results (40), we suspect two false positive results in our study (Table 5), and we witnessed some infrequent confirmed false positive IDN results in routine care after the end of the study.

Conclusion

Based on our large experience, IDN use in walk-in centres with an optimized sampling method in acute symptomatic participants can be achieved safely without the need for laboratory confirmation of negative results. In this context, IDN can be considered a stand-alone testing option. Such deployment accelerates contact tracing of positive cases and reduces the burden on laboratories, while increasing access to testing.

Authors' statement

IGS — Conceived the original idea, acquired the financial support, performed literature searches, drafted the manuscript, review and editing
JL — Conceived the original idea and statistical analysis, performed initial literature searches, wrote the first draft, supervised the project
JD — Conceived the original idea and statistical analysis, performed additional literature searches, drafted the manuscript, performed additional literature searches, performed data curation and statistical analyses, supervised the project
MJW — Collected the data and contributed to laboratory content of the manuscript
FB — Collected the data and contributed to the analysis and data curation
LR — Provided resources, validated methodology and feasibility, supervised the project
JH — Collected the data and contributed to laboratory content of the manuscript
JBS — Collected the data and contributed to laboratory content of the manuscript
MP — Collected the data and contributed to laboratory content of the manuscript
SB — Collected the data and contributed to laboratory content of the manuscript
VD — Collected the data and contributed to laboratory content of the manuscript
ACL — Performed data curation and statistical analyses, performed additional literature searches, drafted the manuscript, visualized data presentation, review and editing, supervised the project

All authors approved the final version to be published and agreed to be accountable for all aspects of the work.

The content and view expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Competing interests

None.

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OUTBREAK

COVID-19 outbreak in a long-term care facility in Kelowna, British Columbia after rollout of COVID-19 vaccine in March 2021

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Abstract

Background: In March 2021, a coronavirus disease 2019 (COVID-19) outbreak was declared at a large long-term care and short stay facility in British Columbia, Canada—well after introduction of the vaccination program in long-term care facilities that resulted in a dramatic decline in the number of outbreaks in this type of setting. The objective of this study is to provide the descriptive epidemiology of this outbreak, in the context of partial immunization of both residents and staff at the facility.

Methods: The cases' information was extracted from a provincial information system (Panorama). Descriptive analysis was performed using Microsoft Excel and SAS. Outbreak management controls included, but were not limited to, asymptomatic testing and efforts to increase vaccination.

Results: Twenty-six cases among the 241 resident and three cases among the 418 staff (corresponding to attack rates of 10% and less than 1%, respectively) were identified. The attack rate in residents was considerably lower than the average attack rate for COVID-19 outbreaks in long-term care facilities before the vaccine rollout. Seventeen resident cases were either partially or fully immunized. Four of the eight hospitalized cases and two of the three deceased cases were partially immunized. Seventeen cases were temporary stay residents. The three staff cases were not vaccinated. Ten cases were identified as part of asymptomatic testing.

Conclusion: Introduction of vaccination at facilities contributed to lower attack rates and higher numbers of asymptomatic cases in this outbreak. Screening asymptomatic individuals identified additional cases among vaccinated residents. Findings underscore the importance of achieving high vaccine coverage, including among temporary stay residents, to prevent virus introduction and subsequent unrecognized transmission opportunities.

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Keywords: long-term care, outbreak, COVID-19 vaccine, descriptive epidemiology

Introduction

The coronavirus disease 2019 (COVID-19) pandemic, declared in March 2020, has physically and mentally affected many lives, especially seniors and individuals living with underlying medical conditions. Long-term care (LTC) facilities experienced an increase in outbreaks, as well as increased morbidity and mortality amongst staff and residents (1,2).

Vaccination of frontline staff has been found to be highly effective in preventing COVID-19 infection (3); however, older adults with multiple underlying comorbidities were one of the groups not included in the preauthorization vaccine effectiveness clinical trials and are expected to have lower immunogenicity from vaccination (4). Other studies in this population have focused on vaccine effectiveness in the post-marketing phase in individuals with partial versus complete immunization (3,5). A recent publication on vaccine effectiveness among residents of nursing homes in the United States showed a reduction in the number of infections and milder symptoms among individuals who were partially or fully vaccinated (6). In addition, the emergence of new variants of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has raised questions about vaccine effectiveness against novel strains of the virus (7–9).

In March 2021, Interior Health (IH; a regional health authority in British Columbia, Canada) reported the end of the third wave of the pandemic. Although the incidence rate of COVID-19 infection in IH was decreasing at that time, the prevalence of variants of concern was starting to increase, particularly the Alpha (B.1.1.7) variant. Providing the COVID-19 vaccine to seniors in LTC facilities in British Columbia resulted in a significant decrease in the number of COVID-19 outbreaks and deaths at these facilities (10). However, a COVID-19 outbreak occurred at a large LTC facility three months after the start of vaccination program. On March 5, 2021, IH Communicable Disease Unit and Infection Prevention and Control (IPAC) were notified of a positive COVID-19 result in a resident of a LTC facility who had been admitted in December 2020 to the short stay unit (SSU) from a nearby acute care site for rehabilitation. The resident, who had hypothyroidism and hypertension as their underlying medical condition and who had received their second dose of the Pfizer-BioNTech COVID-19 vaccine eight days prior to symptom onset, was isolated in a private room with mild symptoms, including sore throat, cough, congestion and fatigue.

The same day, it was discovered that another resident, who was unknowingly exposed to a COVID-19-positive roommate in an acute care setting outbreak, had recently been transferred back to a different unit in the same LTC facility. This resident underwent testing on March 6, 2021, and was found to be COVID-19 positive. This resident had been admitted to the acute care site for renal failure and sepsis secondary to urinary tract infection and the only COVID-19 infection symptom was fatigue. The acute care setting outbreak included five staff and five patients and was declared over on April 7, 2021.

The LTC facility was unique in that it comprised 181 beds divided between four LTC units and included a 60-bed SSU as well. Resident rooms were a mix of private, semi-private and multi-bedrooms. There were approximately 418 staff working at the facility during the outbreak: approximately 70 SSU staff and 208 LTC staff, plus 140 staff working in both areas of the facility.

The IPAC measures at the facility before the outbreak began included the restrictions that were in place for LTC facilities in British Columbia as per the provincial guidelines (11). These measures included but were not limited to daily screening of staff and residents, use of appropriate personal protective equipment, regular hand hygiene and frequent environmental cleaning. Social visits were restricted to one designated visitor, subject to strict symptom screening, at two meters of distance with personal protective equipment in place. Staff were restricted to work at a single LTC site. The facility was required to perform daily reports of any symptomatic residents or staff.

Outbreak control measures

A subgroup of the Communicable Disease Unit called the Adult Care Facility COVID-19 Response Team was created as a pandemic response to oversee COVID-19 outbreaks related to LTC facilities in early 2020. The Adult Care Facility Team assembled an outbreak management team including the local Medical Health Officer, IPAC, Environmental Public Health, Epidemiology, Community Care Licensing, Clinical Operations, Workplace Health and Safety, Emergency Response Team, Communications and representatives of the facility. Introduction of outbreak management measures started within a day of the identification of the index case.

After the initial outbreak management team assessment, an outbreak was declared and ongoing daily meetings occurred. Residents were isolated to their private rooms or beds from the start of the outbreak until a cohorting plan was developed. Ongoing screening occurred daily to identify newly symptomatic staff or residents who were then placed in isolation, tested for COVID-19 and reported as soon as possible. New positive cases were added to an outbreak line list. Symptomatic staff were excluded from work. Staff were cohorted and started to work exclusively at designated units within the facility. Contact tracing was performed as positive cases were identified, with exposed individuals cohorted and pre-emptively placed in isolation.

The IPAC support provided education and direction on infection control practices. Resident activities were cancelled and meals were served only at resident rooms. Unimmunized residents and staff were immediately offered the vaccine. Vaccination of the recently infected residents and staff was delayed due to natural immunity following infection. Asymptomatic testing was performed to detect cases and prevent unrecognized facility transmission.

The objective of this report is to provide descriptive epidemiology for a COVID-19 outbreak in a large LTC facility, which was more open to movement of residents and staff owing to the unique co-location of an SSU, in the context of partial immunization of both residents and staff.

Methods

Case finding and data collection

The IPAC and Communicable Disease Unit staff began an investigation of residents and staff, under the direction of the Medical Health Officer. Facility-related cases were defined as per provincial outbreak guidelines (12). Cases were defined as individuals with a positive COVID-19 polymerase chain reaction test result, regardless of symptoms and standardized information was collected on any confirmed cases (13). Investigation was completed for any additional case starting February 18, 2021—

one incubation period prior to the first identified case—for likely linkage to the outbreak.

Specimen collection and testing were undertaken following provincial guidelines. Flocked nasopharyngeal swabs (residents) or saline gargles (staff) were collected, then were rapidly transported to Kelowna General Hospital laboratory for testing on the Panther Fusion® SARS-CoV-2 Assay (Hologic, San Diego, California, United States) or the Allplex™ 2019-nCOV Assay (Seegene, Seoul, South Korea). Positive specimens were referred to British Columbia Centre for Disease Control Public Health Laboratory for whole genome sequencing.

Information about reportable cases, including their immunization records, was available through Panorama, the British Columbia Public Health Communicable Disease Unit's integrated records system (13). Staff immunization records were extracted from Panorama using Public Health Environment for Integrated data Extracts (PHENIX). Immunization records for residents that were not cases were provided by Interior Health's Strategic Information team. Descriptive analyses were performed using Microsoft Excel 2010 and SAS version 9.4.

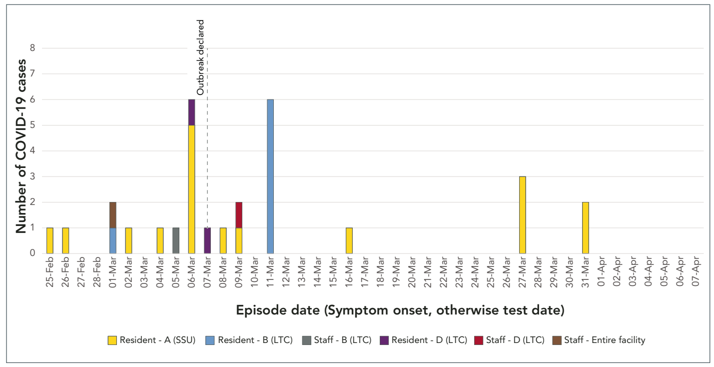
Unvaccinated cases are defined as individuals who either had not received a vaccine or had received only one dose of vaccine within 21 days of episode date (symptom onset when available, otherwise specimen collection date for first positive test). Partially vaccinated individuals had received the first dose of vaccine more than 21 days before their episode date and either had not received the second dose of vaccine or had received the second dose within seven days of their onset of symptoms. Individuals with episode dates more than seven days after receiving their second dose of vaccine are considered fully vaccinated. This definition was adapted provincially for partial and full vaccination at the time that the outbreak happened (14).

Asymptomatic COVID-19 polymerase chain reaction testing was performed in a ring screen model, with the highest-risk asymptomatic resident and staff contacts tested first, and with subsequent testing in more remote contacts as additional cases were identified. Asymptomatic testing was performed at five to seven-day intervals, in multiple rounds based on the level of COVID-19 activity in the staff and residents on a particular unit.

Results

A resident of SSU was identified as the first case with disease onset on February 25, 2021. Over the next two weeks, the disease was spread to staff and two other units in the facility. The outbreak was declared over on May 5, 2021 (**Figure 1**).

Figure 1: Epidemic curve of outbreak cases by episode date[a,b], unit and role (resident/staff) (N=29)



Abbreviations: COVID-19, coronavirus disease 2019; LTC, long-term care; SSU, short stay unit
[a] Episode date refers to symptom onset date if available otherwise specimen collection date for earliest positive test
[b] There was no additional cases detected after April 2, 2021

When the outbreak was declared, resident immunization rates were similar for the LTC units and the SSU for COVID-19 vaccine dose one (91.1% vs 87.7%, respectively) but were different for vaccine dose two (82.8% of LTC residents and 22.8% of SSU residents had received their second dose). Staff full vaccination rate decreased slightly from 58% to 54% during the course of the outbreak; however, partial vaccination rate increased from 6% to 19% from the date that the outbreak was declared until it was declared over.

Ten of 29 cases were asymptomatic: all were resident cases and were identified as part of the asymptomatic testing conducted in response to the outbreak (**Table 1**). Six of the ten asymptomatic cases were fully vaccinated. Eight of the 26 resident cases were hospitalized and there were three COVID-19-related deaths. All deaths occurred among cases that were at least partially vaccinated and four of the eight hospitalizations were also among partially vaccinated cases (**Table 2**).

Table 1: Characteristics of COVID-19 cases included in the outbreak investigation by role (resident/staff) (N=29)

Characteristics of the cases	Residents		Staff		Total	
	Number	%	Number	%	Number	%
Total cases	26	100.0%	3	100.0%	29	100.0%
Sex						
Males	4	15.4%	1	33.3%	3	10.3%
Females	16	61.5%	2	66.7%	10	34.5%
Age group						
Younger than 30 years	0	0.0%	0	0.0%	0	0.0%
30–39 years	0	0.0%	1	33.3%	1	3.4%

Table 1: Characteristics of COVID-19 cases included in the outbreak investigation by role (resident/staff) (N=29) (*continued*)

Characteristics of the cases	Residents		Staff		Total	
	Number	%	Number	%	Number	%
40–49 years	1	3.8%	0	0.0%	1	3.4%
50–59 years	0	0.0%	2	66.7%	2	6.9%
60–69 years	0	0.0%	0	0.0%	0	0.0%
70–79 years	5	19.2%	0	0.0%	5	17.2%
80–89 years	11	42.3%	0	0.0%	11	37.9%
90+ years	9	34.6%	0	0.0%	9	31.0%
Unit						
A (SSU)	17	65.4%	0	0.0%	17	58.6%
B (LTC)	7	26.9%	1	33.3%	8	27.6%
D (LTC)	2	7.7%	1	33.3%	3	10.3%
Entire facility	0	0.0%	1	33.3%	0	0.0%
Vaccination status						
Unvaccinated	9	34.6%	3	100.0%	11	37.9%
Partially vaccinated	9	34.6%	0	0.0%	10	34.5%
Fully vaccinated	8	30.8%	0	0.0%	8	27.6%
Chronic medical conditions[a]						
Any (total)	17	65.4%	0	0.0%	17	58.6%
Cardiac disease	13	50.0%	0	0.0%	14	48.3%
Pulmonary disease	5	19.2%	0	0.0%	7	24.1%
Kidney disease	2	7.7%	0	0.0%	5	17.2%
Other	6	23.1%	0	0.0%	10	34.5%
None	9	34.6%	3	100.0%	12	41.4%
Disease status						
Asymptomatic	10	38.5%	0	0.0%	10	34.5%
Symptomatic	5	19.2%	3	100.0%	8	27.6%
Hospitalized	8	30.8%	0	0.0%	8	27.6%
ICU	0	0.0%	0	0.0%	0	0.0%
Death	3	11.5%	0	0.0%	3	10.3%
SARS-CoV-2 lineage						
B.1.160	16	61.5%	2	66.7%	18	62.1%
B.1.36	1	3.8%	0	0.0%	1	3.4%
Insufficient nucleic acid for WGS	9	34.6%	1	33.3%	10	34.5%
Ct value						
Less than 30.0	17	65.4%	2	66.7%	19	65.5%
30.0 or higher	9	34.6%	1	33.3%	10	34.5%

Abbreviations: COVID-19, coronavirus disease 2019; Ct value, cycle threshold value; ICU, intensive care unit; LTC, long-term care; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SSU, short stay unit; WGS, whole genome sequencing

[a] Breakdown of type chronic medical conditions may add to more than 100% as it was possible for cases to have more than one condition

Table 2: Characteristics of COVID-19 cases included in the outbreak investigation by vaccination status (N=29)

Characteristics of the cases	Unimmunized		Partially vaccinated		Fully vaccinated	
	Number	%	Number	%	Number	%
Total cases	12	100.0%	9	100.0%	8	100.0%
Sex						
Males	3	25.0%	2	20.2%	1	12.5%
Females	9	75.0%	8	88.9%	7	87.5%
Age group						
Younger than 30 years	0	0.0%	0	0.0%	0	0.0%
30–39 years	1	8.3%	0	0.0%	0	0.0%
40–49 years	1	8.3%	0	0.0%	0	0.0%
50–59 years	2	16.7%	0	0.0%	0	0.0%
60–69 years	0	0.0%	0	0.0%	0	0.0%
70–79 years	2	16.7%	1	11.1%	2	25.0%
80–89 years	5	41.7%	3	33.3%	3	37.5%
90+ years	1	8.3%	5	55.6%	3	37.5%
Role						
Resident	9	75.0%	9	100.0%	8	100.0%
Staff	3	25.0%	0	0.0%	0	0.0%
Unit						
A (SSU)	8	66.7%	7	77.8%	2	25.0%
B (LTC)	1	8.3%	1	11.1%	6	75.0%
D (LTC)	2	16.7%	1	11.1%	0	0.0%
Entire facility	1	8.3%	0	0.0%	0	0.0%
Chronic medical conditions[a]						
Any (total)	5	41.7%	7	77.8%	5	62.5%
Cardiac disease	3	25.0%	5	55.6%	5	62.5%
Pulmonary disease	2	16.7%	2	22.2%	1	12.5%
Kidney disease	1	8.3%	0	0.0%	1	12.5%
Other	4	33.3%	1	11.1%	1	12.5%
None	7	58.3%	2	22.2%	3	37.5%
Disease status						
Asymptomatic	4	33.3%	0	0.0%	6	75.0%
Symptomatic	4	33.3%	3	33.3%	1	12.5%
Hospitalized	4	33.3%	4	44.4%	0	0.0%
ICU	0	0.0%	0	0.0%	0	0.0%
Death	0	0.0%	2	22.2%	1	12.5%
SARS-CoV-2 lineage						
B.1.160	8	66.7%	6	66.7%	4	50.0%
B.1.36	1	8.3%	0	0.0%	0	0.0%
Insufficient nucleic acid for WGS	3	25.0%	3	33.3%	4	50.0%
Ct value						
Less than 30.0	10	83.3%	6	66.7%	3	37.5%
30.0 or higher	2	16.7%	3	33.3%	5	62.5%

Abbreviations: COVID-19, coronavirus disease 2019; Ct value, cycle threshold value; ICU, intensive care unit; LTC, long-term care; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SSU, short stay unit; WGS, whole genome sequencing

[a] Breakdown of type chronic medical conditions may add to more than 100% as it was possible for cases to have more than one condition

Of the 26 resident cases, 17 were fully or partially vaccinated (Table 1). All three staff cases within this outbreak were unvaccinated. The majority of cases that were considered fully vaccinated break through cases was from Unit B, where residents had higher opportunity to get their second dose of vaccine compared with other units. The majority of cases that were considered unvaccinated was from the SSU (Table 2).

Despite its smaller bed capacity compared with the other facility units, 17 of the 26 cases were from the SSU where the index case occurred. The attack rate at SSU was 28%. A higher proportion of resident cases were females with ages above 80 years that reflected the demographic profile in the facility. Seventeen of 26 resident cases (65%) had some underlying chronic medical condition, and this proportion was higher among residents from the LTC unit (**Table 3**). The disease outcomes were more prominent amongst the resident of SSU as there were higher proportion of severe outcomes that occurred in this unit compared with the other two units.

All the samples from resident cases that were successfully sequenced at SSU and Unit B were identified as the SARS-CoV-2 lineage B.1.160 (n=13). All thirteen B.1.160 cases cluster together within three mutations. However, one resident case at Unit D was successfully sequenced and was genetically different, identified as B.1.136 lineage (**Figure 2**). Ten cases had cycle threshold (Ct) values over 30.0, nine of whom were asymptomatic cases. Eight of ten cases with higher Ct values were among those considered at least partially vaccinated (Table 1 and Table 2).

The average attack rate at the facility was 10% in residents and less than 1% in staff. The resident attack rate in the short stay unit of the facility was 22% compared with 4% in the LTC units.

Clinical Operations was able to arrange on site vaccination for residents. Staff were provided with educational material about vaccination and were strongly encouraged to access vaccine through local public health facilities. The proportion of resident vaccination rate did not change significantly during the course of the outbreak. Staff immunization with at least one dose of vaccine increased from 63.8% to 72.5%.

Table 3: Characteristics of COVID-19 resident cases included in the outbreak investigation by unit (N=26)

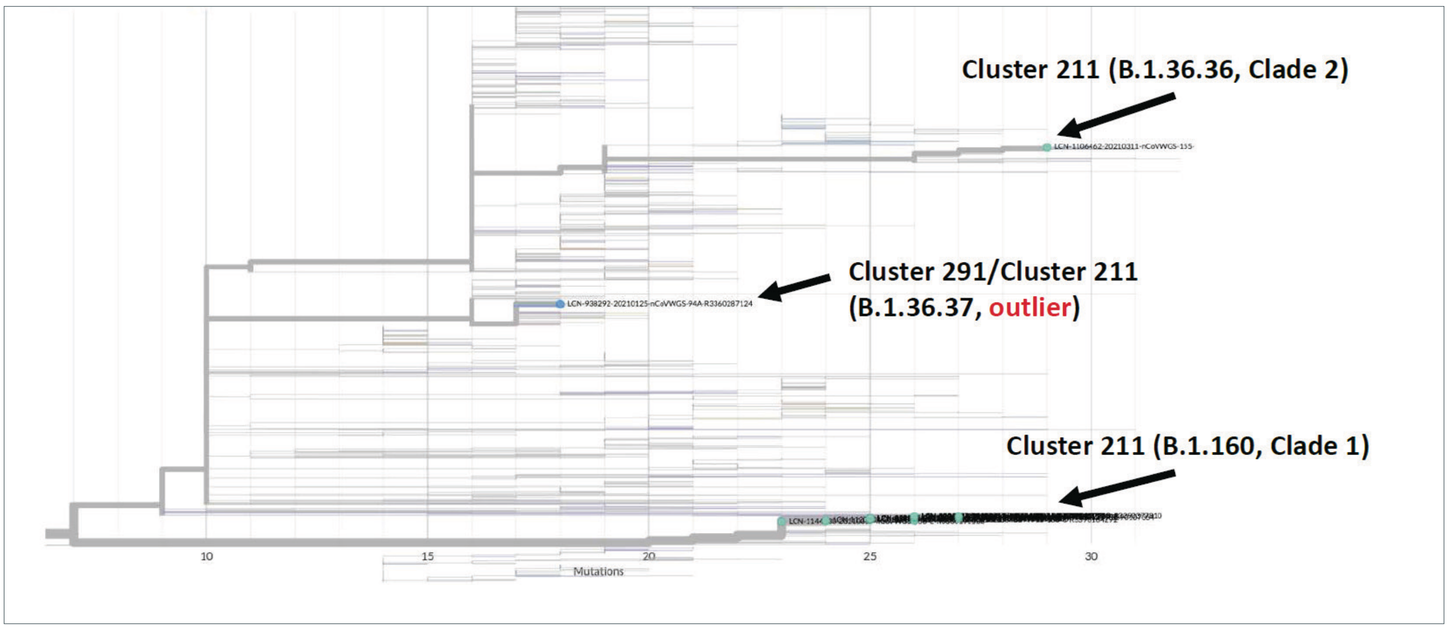
Characteristics of the cases	Unit A (SSU)		Unit B (LTC)		Unit D (LTC)	
	Number	%	Number	%	Number	%
Total resident cases	17	100.0%	7	100.0%	2	100.0%
Sex						
Males	2	11.8%	1	14.3%	0	0.0%
Females	15	88.2%	6	85.7%	2	100.0%
Age group						
Younger than 70 years	0	0.0%	0	0.0%	1	50.0%
70–79 years	4	23.5%	1	14.3%	0	0.0%
80–89 years	9	52.9%	2	28.6%	0	0.0%
90+ years	4	23.5%	4	57.1%	1	50.0%
Vaccination status						
Unvaccinated	8	47.1%	0	0.0%	1	50.0%
Partially vaccinated	7	41.2%	1	14.3%	1	50.0%
Fully vaccinated	2	11.8%	6	85.7%	0	0.0%
Chronic medical conditions[a]						
Any (total)	10	58.8%	5	71.4%	2	100.0%
Cardiac disease	7	41.2%	5	71.4%	1	50.0%
Pulmonary disease	4	23.5%	1	14.3%	0	0.0%
Kidney disease	1	5.9%	1	14.3%	0	0.0%
Other	4	23.5%	1	14.3%	1	50.0%
None	7	41.2%	2	28.6%	0	0.0%
Disease status						
Asymptomatic	4	23.5%	5	71.4%	1	50.0%
Symptomatic	4	23.5%	0	0.0%	1	50.0%
Hospitalized	7	41.2%	1	14.3%	0	0.0%
ICU	0	0.0%	0	0.0%	0	0.0%
Death	2	11.8%	1	14.3%	0	0.0%

Table 3: Characteristics of COVID-19 resident cases included in the outbreak investigation by unit (N=26) (*continued*)

Characteristics of the cases	Unit A (SSU)		Unit B (LTC)		Unit D (LTC)	
	Number	%	Number	%	Number	%
SARS-CoV-2 lineage						
B.1.160	12	70.6%	4	57.1%	0	0.0%
B.1.36	0	0.0%	0	0.0%	1	50.0%
Insufficient nucleic acid for WGS	5	29.4%	3	42.9%	1	50.0%
Ct value						
Less than 30.0	13	76.5%	3	42.9%	1	50.0%
30.0 or higher	4	23.5%	4	57.1%	1	50.0%

Abbreviations: COVID-19, coronavirus disease 2019; Ct value, cycle threshold value; ICU, intensive care unit; LTC, long-term care; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SSU, short stay unit; WGS, whole genome sequencing
[a] Breakdown of type chronic medical conditions may add to more than 100% as it was possible for cases to have more than one condition

Figure 2: Phylogenetic tree demonstrating severe acute respiratory syndrome coronavirus 2 genetic diversity of the cases linked to the outbreak[a]



Abbreviation: SSU, short stay unit
[a] This tree is rooted to the original Wuhan reference strain, and displays sequences based on the number of mutations that differ from this reference strain (x-axis). Cases belonging to the outbreak are displayed as light blue and green dots on the tree tips

Discussion

An outbreak in a LTC Facility in Kelowna represented one of the few LTC outbreaks after introduction of vaccination to this population in British Columbia. The attack rate in residents at the facility was considerably lower than the average attack rate for COVID-19 outbreaks in LTC facilities before the vaccine rollout and the number of asymptomatic cases was relatively higher. To compare the numbers, the average attack rate for COVID-19 outbreaks in LTC facilities before the vaccine rollout was 45% (ranging from 5% to 90%). The average attack rate of the facility outbreaks is calculated based on the information on declared outbreaks and total cases available on British Columbia Centre for Disease Control website (15).

In this outbreak, most of the breakthrough cases were among the partially vaccinated residents. This finding is consistent with two cohort studies that show lower antibody response to first dose of vaccination in population older than 80 years of age (16,17). Six of 10 cases that were identified among the fully vaccinated residents were detected by asymptomatic testing with high Ct values. Similarly, another study demonstrated complete vaccination with messenger ribonucleic acid (mRNA) vaccines to be 94% effective against hospitalization for adults, while partial vaccination was 65% effective against hospitalization for adults older than 65 years of age (18).

The LTC facilities in IH had an overall low vaccination rate (68%) at the time of this outbreak, which contributed to the ongoing transmission. Shared dietary and housekeeping staff between the LTC units and SSU was another factor that likely facilitated introduction of the infection to different units. Despite efforts to increase staff vaccination rate, the rate of full vaccination decreased slightly during the outbreak (from 58% to 54%). The slight decrease was due to staff movement in and out of the facility during the course of outbreak management. Outbreak protocols were successful in increasing the partial vaccination rate among staff. In addition, the structural characteristics of the facility (a large, aging building and multi-bed rooms) likely contributed to the outbreak.

Unit A (short stay unit)

The attack rate was higher in the SSU than in the LTC units. The residents were not required to be vaccinated prior to arrival at SSU and due to the transient nature of resident's visit at this unit, complete immunization rate was lower than LTC side. High turnover at the facility and high volume of traffic through the facility due to rehabilitation services were other factors that likely facilitated transmission within the unit. Recurrent transfers between this unit and a nearby acute care setting increased the need for vigilant screening of the admissions.

The resident partial vaccination rate at this unit was high before the outbreak and did not have a meaningful change during the course of the outbreak; however, staff vaccination rate increased by 10%. The strict outbreak measures and the improved vaccination rate and/or acquisition of natural immunity following infection facilitated outbreak management. However, due to the limited vaccine supply and to accelerate the initiation of vaccination in the population, a decision was made provincially to extend the interval between the first and second dose of vaccination at the beginning of March 2021 (19,20). Therefore, full vaccination of some of the residents and staff was delayed.

All of the cases that required hospitalization at this unit were partially or fully vaccinated and had chronic medical conditions. Two deaths were reported in partially or fully vaccinated individuals with multiple underlying chronic medical conditions. Their deaths were primarily related to their underlying conditions and COVID-19 infection was a contributory factor.

Unit B (long-term care)

The cases at this unit were linked to the SSU (Figure 2). While all the confirmed cases were considered partially or fully vaccinated, these definitions rely on an assessment of status at episode date. Most of the cases diagnosed had Ct values in higher ranges and were asymptomatic. It is possible that the cases may have had earlier infections that were not detected until they underwent asymptomatic testing. It is also possible that since most of these cases were fully vaccinated, they had lower viral load and decreased severity of infection.

Unit D (long-term care)

The initial case at this unit was transferred to the LTC from an acute care setting. This resident then transmitted infection to one other resident on the unit. These two cases identified on this unit were unvaccinated and were transferred to the SSU early in the course of the outbreak for cohorting purposes. The viral lineage identified for these cases was the same as that from the acute care facility outbreak, demonstrating that these two cases were unrelated to the outbreak in the rest of the facility.

Strengths and limitations

This is one of the initial studies describing an outbreak in a LTC setting after the introduction of the COVID-19 vaccination. It includes a comprehensive assessment of the cases that were partially or fully vaccinated to contribute to the growing body of evidence concerning the attack rate and disease outcome in immunized individuals. In addition, whole genome sequencing and phylogenetic assessment supplemented the epidemiologic investigation to clarify the disease transmission patterns. This study demonstrates the complexity of managing an outbreak in this setting and can inform outbreak prevention and management in LTC facilities.

A number of factors limits this study. A proper assessment of vaccine effectiveness and disease outcome requires a larger sample size to compare between vaccinated and unvaccinated groups, in order to adjust for confounding factors that can contribute to severe symptoms in population with advanced age. However, the number of cases linked to this outbreak was small and the cases were heterogeneous and belonged to different cohorts with distinct lineages of virus, limiting the power of statistical analysis. In addition, due to the specific characteristics of the outbreak and the facility, the findings may not be generalizable to other settings.

Conclusion

This descriptive analysis is consistent with other investigations demonstrating that partial or complete COVID-19 vaccination provides protection for residents of LTC facilities, prevents severe infection and outcomes and highlights the importance of vaccination in these settings. However, breakthrough infections occur, and may be more common in elderly individuals due to their less robust immune response to vaccination (4,18,19). This highlights the importance of continued vigilance regarding general IPAC measures, such as use of appropriate personal protective equipment, routine symptom screening and rapid isolation and testing of individuals who experience COVID-19 symptoms. In addition, since asymptomatic or mild infection appears more common in immunized individuals, asymptomatic testing is a critical tool for identifying and isolating cases before further transmission occurs.

Authors' statement

FS — Writing original draft, review and editing, project administration
BG — Methodology and analysis, writing review and editing
MS — Methodology and analysis, writing review and editing
AW — Conceptualization, investigation and resources, writing original draft, review and editing
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MA — Investigation and resources, writing review and editing
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Competing interests

None.

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