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Josée G. Lavoie, Razvan G. Romanescu, Alan Katz et Nathan Nickel

Résumé de l'article

Objectives: This article articulates the complexity of modeling in First Nations, Metis, and Inuit contexts by providing the results of a modeling exercise completed at the request of the First Nations Health and Social Secretariat of Manitoba.

Methods: We developed a model using the impact of a previous pandemic (the 2009 H1N1) to generate estimates.

Results: The lack of readily available data has resulted in a model that assumes homogeneity of communities in terms of health status, behaviour, and infrastructure limitations. While homogeneity may be a reasonable assumption for province-wide planning, First Nation communities and Tribal Councils require more precise information in order to plan effectively. Metis and urban Inuit communities, in contrast, have access to much less information, making the role of Indigenous organizations mandated to serve the needs of these populations that much more difficult.

Conclusion: For many years, Indigenous organizations have advocated for the need to have access to current and precise data to meet their needs. The COVID-19 pandemic demonstrates the importance of timely and accurate community-based data to support pandemic responses.

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Modeling the Impact of the COVID-19 Pandemic on First Nations, Metis, and Inuit Communities: Some Considerations

Josée G. Lavoie
University of Manitoba, Canada, josee.lavoie@umanitoba.ca

Razvan G. Romanescu
Centre for Healthcare Innovation, University of Manitoba, Canada, Razvan.Romanescu@umanitoba.ca

Alan Katz
Manitoba Centre for Health Policy, University of Manitoba, Canada, Alan_Katz@cpe.umanitoba.ca

Nathan Nickel
Manitoba Centre for Health Policy, University of Manitoba, Canada, Nathan.Nickel@umanitoba.ca

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Abstract

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Keywords
Infectious diseases, mathematical modeling, public health, Indigenous, Aboriginal, Canada, COVID-19, pandemic

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Across Canada, researchers and health care decision-makers are working to model the potential impact of the COVID-19 pandemic. The goal of modeling is to reduce uncertainty in the face of emerging outbreaks and assist in planning a public health response. For those new to modeling, this form of scholarship requires a significant mind shift—it demands synthesizing a significant, emerging, uneven, and largely non-peer reviewed body of knowledge, making inferences and assumptions, and producing models that can guide decision-making (Jewell et al., 2020). The complexity of modeling is captured very well by various authors (Pastory y Piontti et al., 2019; Weinersmith et al., 2020). The experiences of COVID-19 from New York and Italy early in the pandemic make the impact of "getting it wrong" somewhat palpable.

Modeling the pandemic with First Nations, Metis, and Inuit communities in mind is made more difficult for a number of reasons. First Nations, Metis, and Inuit communities are heterogenous and dispersed. Pandemic planning for urban Indigenous populations cannot simply emulate plans designed for remote communities, and vice versa. This article articulates the complexity of modeling in First Nations, Metis, and Inuit contexts. We begin with an overview of methods. This is followed by a discussion of the complexity of populating modeling formula. We provide an example to illustrate our points. We then turn to sources of data for First Nations, Metis, and Inuit people, and conclude with recommendations.

Modeling Methods

In this article, we present a model based on a compartmental SIR model. This approach requires estimating the number of individuals *susceptible* to being infected ($S(t)$), number of people *infected* ($I(t)$), and number of people who have *recovered* ($R(t)$). Some fairly classical manipulation of this model allows estimating a final size of the epidemic as a function of only the basic reproductive number of the disease (R_0). This estimation is necessary in the absence of current data. The idea then is to estimate hospital utilization by comparing with the final size of a previous epidemic for which detailed information is available.

These models assume a population of N individuals with homogeneous mixing, that is any two individuals have an equal chance of contact. At every point in time, there are S susceptible individuals, I infected individuals, and R removed (through recovery or death). For simplicity, models often assume a fixed population size (N), and no demographic processes (no births or deaths). This approximation is reasonable for closed populations over relatively short timeframes. The dynamics of evolution of the three compartments (S, I, and R) are governed by a system of differential equations.

Populating each component is however far more complex than suggested above. To begin, the basic reproductive number (R_0) and *fatality rate* associated with COVID-19 vary from country to country for a number of reasons. The fatality rate depends on the age of the population, which is likely a proxy for the presence of comorbidity (Arentz et al., 2020; Weston et al., 2020), the number of cases requiring advanced care at any given time, and the robustness of the health care system. As of July 31st, 2020, the World Health Organization (WHO) Dashboard reported 16,812,755 COVID-19 cases worldwide, resulting in 662,095 deaths (3.94% of cases; WHO, 2020a). In comparison, on July 31st, 2020, Canada reported 8,923 fatalities out of 115,619 presumed and confirmed cases (or 7.72%, COVID-19 Canada,

2020). All figures provided above have grown by a factor of 5 to 10 since we began working on this article a few weeks ago and percentages have also changed considerably.

These mortality rates are, however, problematic because they are calculated using confirmed cases as the denominator. At this time, because testing has been focused on priority populations, we do not have a reliable count of how many Canadians have been infected and are asymptomatic. This means that a Canada-specific fatality rate cannot be confirmed. This is true for all countries, with perhaps the exception of Iceland (Gudbjartsson et al., 2020). The same problem exists for calculating the R_0. Transmission depends on exposure—crowded housing promotes transmission, while physical distancing reduces it. When modeling as if a country did not impose any physical distancing or other measures to prevent transmission, the WHO (2020b) considers the range 2 to 2.5 to be most likely. In a paper intended to guide community intervention policies in Alaska, Hennessy (2020) estimated an R_0 of 1.3 for the first 4 weeks, dropping to 1.1 for weeks 5 to 8, and 0.8 for weeks 9 to 12 to be reasonable in an intervention scenario that arguably most resemble containment strategies adopted in Canada. The transferability of these estimates to First Nation, Metis, and Inuit contexts is unknown. At this point, all emerging estimates are based on samples of convenience (Kobayashi et al., 2020).

Despite a rapidly growing body of literature, estimating the impact of COVID-19 in First Nations, Metis, and Inuit communities is challenging. Following a request from the First Nations Health and Social Secretariat of Manitoba, we attempted to model the potential impact of COVID-19 in Manitoba First Nation communities to support planning and decision-making efforts. In our approach, First Nation communities are defined as the geo-political location associated with a First Nation's traditional territory (most often) and now designated as reserve land according to the Indian Act (1985; see also Indigenous and Northern Affairs Canada, 2017). First Nations face unique historical, colonial, social, and environmental circumstances. Although the COVID-19 virus is different and will behave differently than H1N1 both within the host and between hosts, social conditions, access to safe drinking water, crowding, age distribution, and comorbid profiles have not significantly changed since the H1N1 outbreak of 2009 (Katz et al., 2019). International experience seems to indicate that local circumstances have a significant impact on how the pandemic evolves. The 2009 H1N1 pandemic may in time prove to be a good or poor fit. This will be known in hindsight, when the utility of modeling has waned.

We used reports of the impact of H1N1 (Green et al., 2013; Zarychanski et al., 2010) as the starting point for our modeling exercise in order to estimate the impact of COVID-19 under two scenarios:

a. *Unrestricted spread*, where no control measures are implemented; and

b. After the introduction of a comprehensive set of *containment measures*, which could include school closures, shutdown of non-essential businesses, home quarantine for suspected cases, social distancing, and limiting public gathering to no more than 10 people.

Results

Table 1 translates our assumptions into weekly estimates of First Nations requiring hospitalization, based on the H1N1 experience by community. In Scenario A, where communities continue to allow travel from other communities and where quarantine or physical isolation measures are not observed,

our model estimates 1,754.43 positive cases, with 413.97 (24%) requiring intensive hospital care. In Scenario B, where containment measures are observed, only one third of the cases are anticipated.

Table 1. Estimated Number of Manitoba First Nation COVID-19 Related Hospitalizations and Intensive Care Using Mathematical Modeling

	Total population[a]	Population on reserve[b]	Scenario A: Unrestricted (no quarantine or physical isolation measures)		Scenario B: Containment (quarantine and physical isolation policies in place and respected)	
			COVID-19 cases requiring hospitalization[c]	COVID-19 requiring ICU care[d]	COVID-19 cases requiring hospitalization[e]	COVID-19 requiring ICU care[f]
Estimated total	162,780	93,603	1,754.43	413.97	626.41	147.80

Notes. [a] Total First Nations population on and off reserve based on Indigenous Services Canada and Crown–Indigenous Relations and Northern Affairs Canada's Indian Register as at December 31st, 2019 (provided by First Nations Health and Social Secretariat Manitoba).
[b] Total First Nations population on reserve based on Indigenous Services Canada and Crown–Indigenous Relations and Northern Affairs Canada's Indian Register as at December 31st, 2019 (provided by First Nations Health and Social Secretariat Manitoba).
[c,e] Estimated total COVID-19-related hospitalizations. Rates used were 1,077.8/100,000 for when no action is taken, and 384.82/100,000 after containment strategies are introduced. Rate was multiplied by population to generate estimates.
[d,f] Estimated number of COVID-19 that might require intensive care unit (ICU) care, including ventilation, based on Zarychanski et al. (2010) and Green et al. (2013), which implies a rate of 42/(42+136) = 23.6% requiring ICU out of total hospital admissions.

Discussion

Our model is a unique attempt at modeling the pandemic in Indigenous communities. To date, published models specific to racialized communities have primarily focused on Black communities in the USA (Holmes et al., 2020; Millett et al., 2020; Mollalo et al., 2020; Poteat et al., 2020; Sun et al., 2020). We are not aware of any other models being reported in the public sphere.

Although the viruses are different, and are known to behave differently, we used assumptions based on the impact of the 2009 H1N1 epidemic on First Nation communities in Manitoba in our model for a number of reasons. Firstly, the trajectory of H1N1 in First Nation communities in Manitoba was well documented (Green et al., 2013; Zarychanski et al., 2010). Secondly, social determinants are major factors impacting the trajectory of an epidemic. These factors have remained largely unchanged in First Nation communities in Manitoba (Katz et al., 2019). Our approach is justifiable in this context, despite a lack of precedent in the literature.

Models are only as good as the data with which they are built. Variability in the quality of available data and missing data have long been reported by Indigenous organizations. Lavoie and colleagues (2016) have argued that studies that aggregate data regionally or provincially create urban-centric evidence and erase the reality of rural and remote communities. The SIR model is a homogeneous mixing model, which may be appropriate for computing aggregated projections, but has more limited utility when making local predictions. In contrast, agent-based computational models (Shoukat & Moghadas, 2019) produce estimates that are more precise because they are built with individual-level data. This data is

more readily available for First Nations living on reserve in Manitoba and Ontario. Using this data requires access to expertise in programming, and modeling requires substantial computational resources. While university-affiliated faculty members are generally able to access computational resources free of charge from their university, Indigenous organizations committed to data sovereignty and wishing to do their own modeling may not have access to or want to use existing university or government-based computational infrastructure, and yet may not have sufficient resources in their own infrastructure.

It is well documented that Manitoba's 63 First Nation communities are heterogenous in terms of health status and infrastructure, which can impact transmission and severity (Katz et al., 2019). Data on health status and health behaviours (primarily smoking) are needed to estimate the number of First Nations likely to experience severe COVID-19 symptoms, which are caused by a respiratory virus. Communities' ability and opportunity to respond also depend on local infrastructure, which is heterogenous. The First Nations population in Manitoba ranges from 132 to 10,484, with 57.5% of members living on reserve (Indigenous Services Canada, 2020b), and an additional number who travel to their home community to access services when needed (Lavoie et al., 2015). As such, the on-reserve vs. off-reserve dichotomy adopted by Statistics Canada and others often underestimates the pressure on local services. Indigenous Services Canada's (2020a) website shows that 12 First Nations in Manitoba are currently under a long-term boiling water advisory, 1 community since 2004, and 5 communities since 2014. Another 5 communities are under short-term boiling water advisories (Indigenous Services Canada, 2020a). According to Statistics Canada, 40.7% of on-reserve dwellings in Manitoba are considered to be crowded (Chernikova, 2016), which is defined as more than one person per room. Infrastructure shortcomings alone create added risk of transmission.

We recognize some ethical issues associated with modeling for small populations. The model we report on is aggregated at the provincial level. We did provide First Nation decision-makers with a breakdown by Tribal Council to support planning activities. These numbers will not be reported publicly due to the sample size. Likewise, community-level models can be produced to support decision-making but may not be released publicly to protect individual and community-level confidentiality and prevent cross-community comparisons that might result in stigma.

Communities' ability to respond is anchored in local health services. Local access to health services depends on proximity to off-reserve points of care. Existing models of primary healthcare in First Nation, rural, and remote communities vary considerably, predominantly based on historical decisions grounded in convenience and the circumstances of the time, pragmatic considerations often gaged from southern urban perspectives, ability to recruit and retain professionals, and other contextual factors (Lavoie et al., 2010). All communities provide some level of public health and primary prevention programs. Currently there are 22 federally funded nursing stations in remote communities staffed with nurses working with an expanded scope of practice and 3 staffed nursing stations are provincially funded to deliver a limited complement of primary care services (Lavoie et al., in press). Other communities do not have primary care available within their communities ($n = 38$). Table 2 summarizes data access issues for different Indigenous populations.

Table 2. Challenges and Opportunities for Modeling COVID-19 in First Nation, Metis, and Inuit Populations

	Challenges in Estimating	Potential Sources of Data
Population figures and age structure	Little dependable demographic data exists for First Nations not eligible for registration under the Indian Act, Inuit outside of Nunangat, and Metis.	Population data for First Nations who have Status under the Indian Act are kept up to date by Indigenous Services Canada (2020b). Statistics Canada and the governments of Quebec, Newfoundland and Labrador, Nunavut, and the Northwest Territories also publish population reports.
Risk factors associated with severe symptoms and death	The reported severe and critical case ratio is approximately 7-10% (Chan et al., 2020). The applicability of these analysis to First Nations, Metis, and Inuit is unknown. It is generally assumed that all three populations will be at higher risk of severe disease.	Epidemiological studies are produced by all provinces and territories, as well as by the research community to nuance modeling.

Conclusions

Modeling the impact of COVID-19 in First Nations, Metis, and Inuit communities is complicated by the unique circumstances that apply to Indigenous Peoples in Canada. Models that focus on how the disease might progress in a single community once a case has been diagnosed are likely to have a higher reliability than macro-level models developed to support higher level planning. Still, both are useful exercises aiming at reducing uncertainty, and planning for adequate resource allocation. We were able to draw on H1N1 studies conducted in Manitoba to model the potential impact of COVID-19 on First Nations in Manitoba. These studies were sufficiently detailed to support our modeling exercise. This is not necessarily the case for other regions, resulting in additional limitations. Modeling the impact of the pandemic on urban First Nations, Metis, and Inuit population is at this time virtually impossible because dependable population estimates do not exist. At this point in the pandemic, once again, we must recognize that the data we have is least adequate for what are likely the most vulnerable. An overall message we would like to highlight is that Indigenous communities and organizations require accurate data to support their pandemic plans. It is imperative that research be undertaken to document the strengths of existing pandemic plans, trajectory of the COVID-19 pandemic in Indigenous communities, distill lessons learned, and support the refinement of pandemic plans and modeling for a potential second wave of COVID-19 and subsequent pandemics.

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