

The Role of a Resilient Information Infrastructure in COVID-19 Vaccine Uptake in Ontario

Raquel Duchon, Carina Iskander, Hannah Chung, J. Michael Paterson, Jeffrey C. Kwong, Susan E. Bronskill, Laura Rosella and Astrid Guttman

Abstract

The COVID-19 pandemic has highlighted the need for a robust and nimble public health data infrastructure. ICES – a government-sponsored, independent, non-profit research institute in Ontario, Canada – functions as a key component of a resilient information infrastructure and an enabler of data co-production, contributing to Ontario’s response to the COVID-19 pandemic as part of a learning health system. Linked data on the cumulative incidence of infection and vaccination at the neighbourhood level revealed disparate uptake between areas with low versus high risk of COVID-19. These data were leveraged by the government, service providers, media and the public to inform a more efficient and equitable vaccination strategy.

Introduction

As the world has struggled to respond to the COVID-19 pandemic, many jurisdictions have faced the challenges of effectively generating and leveraging accurate, timely data to support decision making, thus highlighting an increased need for robust public health data infrastructure at local, national and global levels (Foraker et al. 2020). Challenges have included difficulty in aggregating local data up to the regional level, interoperability of multiple information systems (Arvisais-Anhalt et al. 2021), an ecosystem mired by data silos (O’Reilly-Shah et al. 2020) and inadequate data governance (Sittig and Singh 2020). Concurrently, the public desire for data and evidence-based policies to combat COVID-19 is strong (Schultz and Ward 2021), as is the demand for up-to-date information on the pandemic, which is evidenced by the ubiquity of “COVID-19 dashboards” (Fareed et al. 2021; Pietz et al. 2020).

Public engagement with data has fuelled a culture of co-production, whereby citizens play a key role in both the formulation and execution of public policy (Whitaker 1980). This phenomenon has been amplified in the current digital age through social media (Linders 2012) and consists of three components: government, citizens and knowledge generators

(the latter comprising academia, research institutes and others) (Tangcharoensathien et al. 2021). Collaboration between these groups results in higher acceptance and compliance with enduring public policies than the more traditional top-down strategies for the implementation of public health policy (Wasi 2000).

Here, we describe how ICES – a government-sponsored, independent, non-profit research institute in Ontario, Canada – functions as both a key component of a “resilient information infrastructure” (Scholl and Patin 2014) and an enabler of data co-production in contributing to Ontario’s response to the COVID-19 pandemic as part of a learning health system (Foraker et al. 2020).

ICES’s involvement was in part enabled by the creation of the Ontario Health Data Platform (2020), in which ICES is a partner and which has brought together data from multiple sources and shared them with scientists across the province, thereby enabling a rapid response to information needs stimulated by the pandemic. This paper also illustrates how timely generation of COVID-19 vaccine coverage data at ICES has been leveraged by the government, public health units, community organizations, clinicians, scientists, the media and the public at large to inform a more efficient and equitable vaccination strategy.

Challenges to Equitable Vaccine Distribution

The COVID-19 pandemic has illuminated and intensified systemic and structural inequities in Canada and elsewhere (Bambra et al. 2020). In the United Kingdom, Black and South Asian people as well as populations living in poor or marginalized areas were substantially more likely to be diagnosed with and die of COVID-19 (Public Health England 2020; Wadhera et al. 2020; Williamson et al. 2020). In New York City and the state of Illinois, US, COVID-19 incidence and death rates were higher in areas with more poverty, crowded households and people of colour (Chen and Krieger 2021). In Canada, areas with the highest proportions of visible minorities had

COVID-19-related death rates that were close to two times higher than areas with the lowest proportions; in Quebec and Ontario, the comparable death rate was three times higher, and in British Columbia, it was more than 10 times higher (Statistics Canada 2021). In Ontario, individuals have been at increased odds of a COVID-19 diagnosis and related hospitalizations and deaths if they live in areas with high household density, low educational attainment and larger proportions of recent immigrants (Sundaram et al. 2020), challenging social determinants of health and measures of income inequality (Mishra et al. 2021), higher ethno-cultural diversity (Ontario Agency for Health Protection and Promotion 2020a) and neighbourhood material deprivation (Ontario Agency for Health Protection and Promotion 2020b). Immigrants, refugees and other newcomers, who make up roughly 25% of the Ontario population and are more likely than the Canadian-born to be essential workers, accounted for 44% of all COVID-19 cases in the first wave (Guttmann et al. 2020). Finally, data from Toronto Public Health indicate the high toll of disease on racialized communities: where valid data on race were collected, 76% of reported cases and 67% of hospitalizations occurred among racialized individuals, although this group accounts for only 52% of the population (City of Toronto 2021).

These data were leveraged by the government ... and the public to inform a more efficient and equitable vaccination strategy.

In Canada, the National Advisory Committee on Immunization (NACI) develops evidence-based recommendations on the use of authorized vaccines (Desai et al. 2015). In anticipation of an initial scarcity of COVID-19 vaccines, NACI released a document in November 2020 that identified the following key populations for early COVID-19 immunization: people at high risk for severe illness and death, those most likely to transmit to high-risk individuals, essential workers and people with elevated risk for infection due to living or working conditions or disproportionate consequences (i.e., Indigenous communities) (Government of Canada 2020). NACI also emphasized that the vaccine rollout should be informed by an “ethics, equity, feasibility and acceptability framework” (Ismail et al. 2020: 5861). Ontario released its three-phase vaccination strategy in December 2020. The first phase targeted seniors in congregate living settings, healthcare workers, Indigenous people, chronic homecare recipients and adults aged 80 years and older. The second phase targeted adults aged 60–79 years in decreasing five-year age increments, individuals in other high-risk congregate settings (such as shelters and penitentiaries), individuals with high-risk chronic

health conditions and their caregivers and people unable to work from home (Ontario COVID-19 Vaccine Distribution Task Force 2020a). Shortly thereafter, the Ontario government released its Ethical Framework for COVID-19 Vaccine Distribution, which emphasizes equity and fairness as key pillars underpinning vaccine distribution in the province (Ontario COVID-19 Vaccine Distribution Task Force 2020b).

In March 2021, the Ontario government announced that it would allocate up to 920,000 additional doses to the 13 of 34 public health units that had historic and ongoing high rates of COVID-19 cases and related hospitalizations and deaths. However, eligibility criteria at the time remained primarily age based, and as of the beginning of April 2021, no explicit policies were in place to prioritize communities with large populations of essential workers and high-density households, which were disproportionately affected by COVID-19 (Government of Ontario 2021a). Modelling from Ontario’s Science Table showed that a vaccine distribution strategy based on a combination of age and residence in neighbourhoods with the highest burden of COVID-19 would lead to more effective containment of SARS-CoV-2 in the broader population in comparison to a strategy based on age alone (Brown et al. 2021). In addition, the experiences of the UK and the US, where vaccine supplies had allowed an earlier rollout to younger populations, suggested that important inequities had emerged. Black people and individuals living in more deprived neighbourhoods had lower vaccination rates in the UK (The OpenSAFELY Collaborative et al. 2021) and in New York City (NYC Health 2021). Important considerations included structural barriers such as access to the Internet to book appointments, the need for time off work and transportation to attend clinics (Zhang and Fisk 2021), as well as, in some cases, distrust owing to racism in healthcare and the historical unethical treatment of the Black community in research studies (Momplaisir et al. 2021).

Contribution of ICES’s Linked Data Infrastructure to the Vaccine Rollout

Considering the emerging international evidence, ICES undertook analyses to characterize the state of vaccine coverage in Ontario as of March 29, 2021. Decades of experience conducting epidemiologic research using healthcare and demographic data allowed ICES to exploit a robust information infrastructure consisting of not only rich, population-based data holdings but also a network of expert staff and scientists, a strong track record of developing strategic partnerships and a proven system of data governance. The analytics to support the vaccine strategy were enabled by the linkage of information on the cumulative incidence of infection, severe outcomes and vaccination at the neighbourhood level.

Neighbourhood cumulative risk for COVID-19 was determined using a comprehensive provincial testing database and calculated from the beginning of the pandemic. Geographic neighbourhoods were defined using postal forward sortation areas (FSAs), each identified by the first three characters of its postal code. FSAs were then grouped into population-based deciles (each representing a neighbourhood risk group) based on the cumulative incidence of laboratory-confirmed SARS-CoV-2 infection among residents not living in long-term care facilities within each FSA, as of March 28, 2021. Data on vaccinations were obtained from the provincial registry established to record all COVID-19 vaccinations administered in Ontario (COVaxON). Within deciles, individuals were stratified by age group. Vaccine coverage was defined as the number of community-dwelling residents in each age group and neighbourhood risk stratum who received at least one dose of vaccine, divided by the total number of residents in that stratum. The Registered Persons Database, which contains information on persons registered with the Ontario Health Insurance Plan, was used to determine both the postal code and corresponding FSA for each resident and the population for each age–FSA risk stratum.

Table 1a (available online at longwoods.com/content/26553) shows our initial findings on March 29, 2021. Overall vaccine coverage (of at least one dose) among Ontario adults was 13%, with the highest coverage among those aged 80 years and older. However, of concern was the magnitude of the disparity that our analyses revealed. Coverage was the lowest (9%) in the FSAs with the highest neighbourhood risk and highest (15%) in the FSAs with the lowest risk. The largest disparity was observed among those aged 80 years and older, the age group that was prioritized for vaccination at that time, with vaccine coverage ranging from 50% to 70% across neighbourhood risk groups; this pattern was also observed among adults younger than 60 years of age.

These initial data were shared with the provincial government and the public at large through the Ontario COVID-19 Science Advisory Table (Sander et al. 2021) and were also posted on the ICES website (<https://www.ices.on.ca/DAS/AHRQ/COVID-19-Dashboard>). We also published downloadable aggregated data files reporting FSA-level weekly COVID-19 percent positivity rates and the cumulative incidence of COVID-19 cases, hospitalizations, deaths and vaccinations. These data files were accessed by many local and national news outlets as well as by other researchers and citizens, who were then able to create additional data visualizations and perform secondary analyses (Hune-Brown 2021; Iveniuk and Leon 2021) to raise public awareness.

On April 6, 2021, less than a week after these data were published, the Ontario government announced plans for a

supplementary vaccination strategy whereby approximately 30% of neighbourhoods were designated as “hot spots” due to their historically high rates of COVID-19-related deaths and hospitalizations (Government of Ontario 2021b). Additional vaccines were allocated to these neighbourhoods, and residents’ age of eligibility was lowered. ICES also provided each public health unit with the numerators and denominators used to calculate disease incidence and vaccine coverage rates for FSAs in their jurisdiction. The public health units, in conjunction with their hospital and community partners, used these FSA-level data to inform local vaccination efforts, including eligibility criteria for and locations of mass vaccination sites and hospital-, pharmacy- and primary care-based clinics as well as pop-up sites at community centres, schools and places of worship (Government of Ontario 2021c).

ICES monitored the strategy’s effectiveness with weekly updates to the grid (biweekly data are shown in Table 1) and an additional visualization emphasizing week-over-week gains by age group (Table 2, available online at longwoods.com/content/26553). Overall, the targeted strategy reduced disparities in vaccine coverage by age group and neighbourhood COVID-19 risk. As the weeks progressed, higher coverage rates were seen in descending age groups, in line with the age-based component of the strategy (Table 1). By May 10, 2021, overall vaccine coverage among adults in Ontario was 46%, and coverage among those younger than 70 years of age, who were the primary focus of the new strategy, was the highest in high-risk neighbourhoods. Particularly striking has been the large week-over-week gains seen among those aged 16–49 years, corresponding with a further allocation of 50% of the province’s vaccines to a number of pop-up clinics open to adults of any age residing in hot spots (Table 2). However, a large absolute difference across neighbourhood risk persisted among those aged 80 years and older, although overall coverage rates in these groups were high at more than 80% (Table 1). Additional work conducted at ICES using linkages to federal immigration data showed that across all age groups and levels of neighbourhood risk, vaccine uptake was lower among immigrants, refugees and other newcomers (ICES 2021). These analyses similarly point to opportunities to improve the vaccination rollout to ensure equity and the greatest impact for controlling COVID-19 in Ontario.

Conclusion

This case study illustrates the tremendous value of government investment in scientific and data infrastructure that allows for timely access to population-based, individual-level data that can be summarized at the local level to meaningfully inform health system decision making. These data insights have been made widely available to the public and community organizations to

support critical, locally driven initiatives to improve access to care. Providing such analyses in near real time helped improve transparency and build trust, both important for effective management of a public health emergency. **HQ**

References

- Arvisais-Anhalt, S., C.U. Lehmann, J.Y. Park, E. Araj, M. Holcomb, A.R. Jamieson et al. 2021. What the Coronavirus Disease 2019 (COVID-19) Pandemic Has Reinforced: The Need for Accurate Data. *Clinical Infectious Diseases* 72(6): 920–23. doi:10.1093/cid/ciaa1686.
- Bambra, C., R. Riordan, J. Ford and F. Matthews. 2020. The COVID-19 Pandemic and Health Inequalities. *Journal of Epidemiology & Community Health* 74(11): 964–68. doi:10.1136/jech-2020-214401.
- Brown, K.A., N.M. Stall, E. Joh, U. Allen, I.I. Bogoch, S.A. Buchan et al. 2021. A Strategy for the Mass Distribution of COVID-19 Vaccines in Ontario Based on Age and Neighbourhood. *Science Briefs of the Ontario COVID-19 Science Advisory Table* 2(10). doi:10.47326/ocsat.2021.02.10.1.0.
- Chen, J.T. and N. Krieger. 2021. Revealing the Unequal Burden of COVID-19 by Income, Race/Ethnicity, and Household Crowding: US County versus Zip Code Analyses. *Journal of Public Health Management & Practice* 27(Suppl. 1): S43–56. doi:10.1097/phh.0000000000001263.
- City of Toronto. 2021. COVID-19: Status of Cases in Toronto. Retrieved May 13, 2021. <<https://www.toronto.ca/home/covid-19/covid-19-latest-city-of-toronto-news/covid-19-status-of-cases-in-toronto/>>.
- Desai, S., S.J. Ismail, R. Lerch, B.F. Warshawsky and I. Gemmill. 2015. Canada's National Advisory Committee on Immunization: Celebrating 50 Years. *Canadian Journal of Infectious Diseases and Medical Microbiology* 26(3): 126–28. doi:10.1155/2015/431428.
- Fareed, N., C.M. Swoboda, S. Chen, E. Potter, D.T.Y. Wu and C.J. Sieck. 2021. U.S. COVID-19 State Government Public Dashboards: An Expert Review. *Applied Clinical Informatics* 12(2): 208–21. doi:10.1055/s-0041-1723989.
- Foraker, R.E., A.M. Lai, T.G. Kannampallil, K.F. Woeltje, A.M. Trolard and P.R.O. Payne. 2020. Transmission Dynamics: Data Sharing in the COVID-19 Era. *Learning Health Systems* 5(1): e10235. doi:10.1002/lrh2.10235.
- Government of Canada. 2020, November 3. Preliminary Guidance on Key Populations for Early COVID-19 Immunization. National Advisory Committee on Immunization (NACI). Retrieved May 13, 2021. <<https://www.canada.ca/en/public-health/services/immunization/national-advisory-committee-on-immunization-naci/guidance-key-populations-early-covid-19-immunization.html>>.
- Government of Ontario. 2021a, April 1. Ontario Extends COVID-19 Vaccination Booking to More Age Groups [News release]. Retrieved May 13, 2021. <<https://news.ontario.ca/en/release/60994/ontario-extends-covid-19-vaccination-booking-to-more-age-groups>>.
- Government of Ontario. 2021b, April 6. Ontario Moving to Phase Two of COVID-19 Vaccine Distribution Plan [News release]. Retrieved May 13, 2021. <<https://news.ontario.ca/en/release/61009/ontario-moving-to-phase-two-of-covid-19-vaccine-distribution-plan>>.
- Government of Ontario. 2021c, April 13. Ontario's COVID-19 Vaccination Strategy Targets High-Risk Neighbourhoods [News release]. Retrieved May 13, 2021. <<https://news.ontario.ca/en/release/61124/ontarios-covid-19-vaccination-strategy-targets-high-risk-neighbourhoods>>.
- Guttmann, A., S. Gandhi, S. Wanigaratne, H. Lu, L.E. Ferreira-Legere, J. Paul et al. 2020, September. *COVID-19 in Immigrants, Refugees and Other Newcomers in Ontario: Characteristics of Those Tested and Those Confirmed Positive, as of June 13, 2020*. ICES. Retrieved May 13, 2021. <<https://www.ices.on.ca/Publications/Atlases-and-Reports/2020/COVID-19-in-Immigrants-Refugees-and-Other-Newcomers-in-Ontario>>.
- Hune-Brown, N. 2021, April 6. The Vaccine Rollout Is Leaving Toronto's Hardest-Hit Postal Codes Behind. *The Local*. Retrieved May 13, 2021. <<https://thelocal.to/the-vaccine-rollout-is-leaving-torontos-hardest-hit-postal-codes-behind/>>.
- ICES. 2021, April 29. *Vaccine Coverage by Neighbourhood COVID-19 Risk in Immigrants, Refugees, and Other Newcomers, up to April 26, 2021*. Retrieved May 13, 2021. <<https://www.ices.on.ca/-/media/Files/COVID-19/ICES-Report-COVID-19-Vaccine-coverage-by-neighbourhood-risk-among-immigrants.ashx>>.
- Ismail, S.J., K. Hardy, M.C. Tunis, K. Young, N. Sicard and C. Quach. 2020. A Framework for the Systematic Consideration of Ethics, Equity, Feasibility, and Acceptability in Vaccine Program Recommendations. *Vaccine* 38(36): 5861–67. doi:10.1016/j.vaccine.2020.05.051.
- Iveniuk, J. and S. Leon. 2021, April. *An Uneven Recovery: Measuring COVID-19 Vaccine Equity in Ontario*. Wellesley Institute. Retrieved May 13, 2021. <<https://www.wellesleyinstitute.com/wp-content/uploads/2021/04/An-uneven-recovery-Measuring-COVID-19-vaccine-equity-in-Ontario.pdf>>.
- Linders, D. 2012. From E-Government to We-Government: Defining a Typology for Citizen Coproduction in the Age of Social Media. *Government Information Quarterly* 29(4): 446–54. doi:10.1016/j.giq.2012.06.003.
- Mishra, S., H. Ma, G. Moloney, K.C.Y. Yiu, D. Darvin, D. Landsman et al. 2021. Increasing Concentration of COVID-19 by Socioeconomic Determinants and Geography in Toronto, Canada: An Observational Study. *medRxiv*. doi:10.1101/2021.04.01.21254585.
- Momplaisir, F., N. Haynes, H. Nkwihoreze, M. Nelson, R.M. Werner and J. Jemmott. 2021. Understanding Drivers of Coronavirus Disease 2019 Vaccine Hesitancy among Blacks. *Clinical Infectious Diseases*. doi:10.1093/cid/ciab102.
- NYC Health. 2021. COVID-19: Data. Retrieved April 29, 2021. <<https://www1.nyc.gov/site/doh/covid/covid-19-data-vaccines.page>>.
- Ontario Agency for Health Protection and Promotion (Public Health Ontario). 2020a. COVID-19 in Ontario – A Focus on Diversity: January 15, 2020 to May 14, 2020. Retrieved May 13, 2021. <<https://www.publichealthontario.ca/-/media/documents/ncov/epi/2020/06/covid-19-epi-diversity.pdf>>.
- Ontario Agency for Health Protection and Promotion (Public Health Ontario). 2020b. COVID-19 in Ontario – A Focus on Material Deprivation: January 15, 2020 to June 3, 2020. Retrieved May 13, 2021. <<https://www.publichealthontario.ca/-/media/documents/ncov/epi/2020/06/covid-19-epi-material-deprivation.pdf>>.
- Ontario COVID-19 Vaccine Distribution Task Force. 2020a, December 11. *Ontario's Vaccine Distribution Implementation Plan*. Government of Ontario. Retrieved May 13, 2021. <<https://files.ontario.ca/moh-covid-19-vaccine-distribution-implementation-plan-en-2020-12-11-v3.pdf>>.
- Ontario COVID-19 Vaccine Distribution Task Force. 2020b, December 29. *Ethical Framework for COVID-19 Vaccine Distribution*. Government of Ontario. Retrieved May 13, 2021. <<https://files.ontario.ca/moh-ethical-framework-for-covid-19-vaccine-distribution-en-2020-12-30.pdf>>.

- Ontario Health Data Platform. 2020, September 17. The Ontario Health Data Platform. Retrieved May 13, 2021. <<https://ohdp.ca/>>.
- O'Reilly-Shah, V.N., K.R. Gentry, W. Van Cleve, S.M. Kendale, C.S. Jabaley and D.R. Long. 2020. The COVID-19 Pandemic Highlights Shortcomings in US Health Care Informatics Infrastructure: A Call to Action. *Anesthesia & Analgesia* 131(2): 340–44. doi:10.1213/ane.0000000000004945.
- Pietz, J., S. McCoy and J.H. Wilck. 2020. Chasing John Snow: Data Analytics in the COVID-19 Era. *European Journal of Information Systems* 29(4): 388–404. doi:10.1080/0960085x.2020.1793698.
- Public Health England. 2020, August. *Disparities in the Risk and Outcomes of COVID-19*. PHE Publications. Retrieved May 13, 2021. <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/908434/Disparities_in_the_risk_and_outcomes_of_COVID_August_2020_update.pdf>.
- Sander, B., P. Juni, B. Schwartz, K. Murty, U. Allen, V. Allen et al. 2021, April 1. *Update on COVID-19 Projections: Science Advisory and Modelling Consensus Tables*. Science Table COVID-19 Advisory for Ontario. Retrieved May 13, 2021. <https://covid19-sciencetable.ca/wp-content/uploads/2021/04/Update-on-COVID-19-Projections_2021.04.01_English-2.pdf>.
- Scholl, H.J. and B.J. Patin. 2014. Resilient Information Infrastructures: Criticality and Role in Responding to Catastrophic Incidents. *Transforming Government: People, Process and Policy* 8(1): 28–48. doi:10.1108/tg-12-2012-0015.
- Schultz, E. and J.K. Ward. 2021. Public Perceptions of Scientific Advice: Toward a Science Savvy Public Culture? *Public Health* 194: 86–88. doi:10.1016/j.puhe.2021.02.007.
- Sittig, D.F. and H. Singh. 2020. COVID-19 and the Need for a National Health Information Technology Infrastructure. *JAMA* 323(23): 2373–74. doi:10.1001/jama.2020.7239.
- Statistics Canada. 2021, March. *COVID-19 in Canada: A One-Year Update on Social and Economic Impacts: Delivering Insights through Data for a Better Canada*. Retrieved May 13, 2021. <<https://www150.statcan.gc.ca/n1/en/pub/11-631-x/11-631-x2021001-eng.pdf>>.
- Sundaram, M.E., A. Calzavara, S. Mishra, R. Kustra, A.K. Chan, M.A. Hamilton et al. 2020. The Individual and Social Determinants of COVID-19 in Ontario, Canada: A Population-Wide Study. *medRxiv*. doi:10.1101/2020.11.09.20223792.
- Tangcharoensathien, V., S. Sirilak, P. Sritara, W. Patcharanarumol, A. Lekagul, W. Isaranuwatthai et al. 2021. Co-production of Evidence for Policies in Thailand: From Concept to Action. *BMJ* 372: m4669. doi:10.1136/bmj.m4669.
- The OpenSAFELY Collaborative, B. MacKenna, H.J. Curtis, C.E. Morton, P. Inglesby, A.J. Walker et al. 2021. Trends, Regional Variation, and Clinical Characteristics of COVID-19 Vaccine Recipients: A Retrospective Cohort Study in 23.4 Million Patients Using OpenSAFELY. *medRxiv*. doi:10.1101/2021.01.25.21250356.
- Wadhera, R.K., P. Wadhera, P. Gaba, J.F. Figueroa, K.E. Joynt Maddox, R.W. Yeh et al. 2020. Variation in COVID-19 Hospitalizations and Deaths across New York City Boroughs. *JAMA* 323(21): 2192–95. doi:10.1001/jama.2020.7197.
- Wasi, P. 2000. “Triangle that Moves the Mountain” and Health Systems Reform Movement in Thailand. *Human Resources for Health Development Journal* 4(2): 106–10.
- Whitaker, G.P. 1980. Coproduction: Citizen Participation in Service Delivery. *Public Administration Review* 40(3): 240–46. doi:10.2307/975377.
- Williamson, E.J., A.J. Walker, K. Bhaskaran, S. Bacon, C. Bates, C.E. Morton et al. 2020. Factors Associated with COVID-19-Related Death Using OpenSAFELY. *Nature* 584: 430–36. doi:10.1038/s41586-020-2521-4.
- Zhang, Y. and R.J. Fisk. 2021. Barriers to Vaccination for Coronavirus Disease 2019 (COVID-19) Control: Experience from the United States. *Global Health Journal* 5(1): 51–55. doi:10.1016/j.glohj.2021.02.005.

About the Authors

Raquel Duchén, RD, MPH, is a senior epidemiologist for the Populations & Public Health (POP) and Primary Care & Health Systems (PCHS) programs at ICES in Toronto, ON. Raquel can be contacted at raquel.duchen@ices.on.ca.

Carina Iskander, MSc, is an epidemiologist for the Life Stage Research Program at ICES in Toronto, ON.

Hannah Chung, MPH, is an associate research methodologist for the POP and PCHS programs at ICES in Toronto, ON.

J. Michael Paterson, MSc, is a scientist and lead of the Chronic Disease and Pharmacotherapy Research Program at ICES in Toronto, ON.

Jeffrey C. Kwong, MD, MSc, is a senior scientist at ICES, a scientist at Public Health Ontario, a family physician with the Toronto Western Family Health Team and a professor of Family Medicine and Public Health at the University of Toronto in Toronto, ON.

Susan E. Bronskill, PhD, is a senior scientist and lead of the Life Stage Research Program at ICES and a professor in the Institute of Health Policy, Management and Evaluation and the Division of Epidemiology, Dalla Lana School of Public Health at the University of Toronto in Toronto, ON.

Laura Rosella, PhD, is an associate professor and PhD program director in the Epidemiology Division of the Dalla Lana School of Public Health at the University of Toronto, an adjunct scientist in the POP program at ICES and a site director at ICES UofT in Toronto, ON.

Astrid Guttmann, MDCM, MSc, is a senior scientist and chief science officer at ICES, a clinician scientist at The Hospital for Sick Children and professor of Paediatrics, Health Policy and Public Health at the Dalla Lana School of Public Health at the University of Toronto in Toronto, ON.