

Canada in the face of the 2009 H1N1 pandemic

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Background Initial public health responses to the 2009 influenza H1N1 pandemic were based on difficult decisions in the face of substantial uncertainty. Policy effectiveness depends critically on such decisions, and future planning for maximum protection of community health requires understanding of the impact of public health responses in observed scenarios.

Objectives In alignment with the objectives of the Pandemic Influenza Outbreak Research Modelling Team (Pan-InfORM) and the Centre for Disease Modelling (CDM), a focused workshop was organized to: (i) evaluate Canada's response to the spring and autumn waves of the novel H1N1 pandemic; (ii) learn lessons from public health responses, and identify challenges that await public health planners and decision-makers;

and (iii) understand how best to integrate resources to overcome these challenges.

Main outcome measures We report on key presentations and discussions that took place to achieve the objectives of the workshop.

Conclusions Future emerging infectious diseases are likely to bring far greater challenges than those imposed by the 2009 H1N1 pandemic. Canada must address these challenges and enhance its capacity for emergency responses by integrating modelling, surveillance, planning, and decision-making.

Keywords Influenza H1N1 pandemic, intervention strategies, policy decision-making, modelling.

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Overview of the workshop

The Institute for Biodiagnostics of the National Research Council, Winnipeg, Canada was the site for a public health workshop on 'The First Influenza Pandemic of the 21st Century: Canada's Response, Lessons Learned, and Challenges Ahead' held on April 19–20, 2010.¹ The workshop, organized by the Pan-InfORM team,² aimed to understand the competing factors in public health and clinical responses to the 2009 H1N1 pandemic, and identify gaps in the current state of knowledge in pandemic research. A particular emphasis was placed on understanding the differential severity of the pandemic in Canada's Aboriginal (First Nations, Inuit, and Métis) populations. With the involvement of Canadian public health administrators, key decision-makers and leading infectious disease modellers, several presentations described challenges in community health protection that need to be addressed to improve health policy, provide more effective clinical and public health services, and strengthen our healthcare system in response to future emerging infectious diseases. The workshop covered several aspects of pandemic mitigation, including vaccination, antiviral therapy and other

community-based interventions that were implemented to protect vulnerable, at-risk and general populations. Targeted strategies were discussed to identify critical factors that are central for evaluating the effectiveness of intervention measures, and determining optimal scenarios for policy design, implementation and resource allocation.

Participants discussed the recent impact of modelling as a decision-support tool within public health agencies and mechanisms to sustain the leadership, partnerships and internships that have emerged over the past year within a multi-disciplinary environment. Extensive discussion took place on the role of models in characterizing the epidemiology of the novel influenza H1N1, providing guidance on optimal disease mitigation strategies, including vaccination and antiviral drugs, and evaluating the cost-effectiveness of intervention measures during the 2009 pandemic.

The epidemiology and impact of the pandemic in Canada, particularly in terms of the frequency and outcomes of severe cases were described, and comparisons were made between the first (spring) and second (autumn) waves of the H1N1 pandemic. Intensive care unit surge capacity was seriously taxed at the peak of the first pandemic wave (June 2009) in the province of Manitoba.^{3–6} While the cases

hospitalized in Canada during the second wave were older and a higher proportion of them reported underlying medical conditions, Canada experienced a relative decline in severity among hospitalized cases between the first and second pandemic waves.⁷ Compared to the first wave, the burden of disease in some groups was significantly reduced during the second wave of this pandemic. Pregnant women and Aboriginal peoples were still at greater risk of severe disease than the general population in the fall wave, but their relative risk decreased considerably compared to the spring wave.⁷ This may reflect the higher levels of pre-existing immunity because of infection acquired in the first wave (e.g., in remote and isolated communities), but likely also to vaccine uptake, dramatic increase in the use of antiviral drugs and wider availability of health resources.^{7,8}

In the context of vaccination, lessons in regulation, guidance, delivery and safety surveillance were presented. Although mock pandemic vaccines based on an H5N1 influenza virus had been in development and under regulatory review for several years prior to the emergence of the novel H1N1 virus, the timing of the pandemic created a number of immediate challenges for vaccine production and the rollout of immunization campaigns. The Canadian pandemic plan⁹ promised enough vaccine for all Canadians and a vaccine order to support this goal was placed based on estimates of coverage (75%) and an expected two-dose schedule. A priority sequencing strategy was developed to address insufficient initial quantities of vaccine and provincial/territorial capacity for mass immunization;¹⁰ this was based on a prioritization framework that was part of the pandemic plan.¹¹ The challenges in rapid rollout of the vaccination strategy included approving a new vaccine prior to the availability of the usual regulatory file, translating limited clinical data on immunogenicity and safety into recommendations, and the need to be particularly vigilant regarding vaccine safety.

While providing an overview of Canada's response to the 2009 pandemic, presentations detailed the outcomes of intervention strategies in various settings, including Aboriginal populations. Despite the relatively mild nature of this pandemic, early outbreaks following the emergence of the novel H1N1 virus disproportionately affected several remote and isolated communities, including First Nation reserves in Northern Manitoba and remote communities in Nunavut. A national working group was created to address the issue of pandemic preparedness and response in remote communities, and produce guidelines for practical considerations in these areas.¹² Other special populations such as children, the elderly and pregnant women were addressed in the context of development of clinical guidelines by the Clinical Care and Antiviral Task Group of the Public Health Agency of Canada.¹³ In pandemic response efforts, Health Canada¹⁴ was responsible for supporting health pro-

motion programmes in First Nations on-reserve and Inuit communities south of 60° and providing primary health-care services in these populations. In this capacity, the department built upon its pre-pandemic planning to support on-reserve communities in updating their pandemic plans; pre-positioning personal protective equipment for frontline healthcare staff in on-reserve nursing stations; providing targeted public messaging; and conducting H1N1 mass vaccinations on reserves. Health Canada also worked in close collaboration with provinces and other federal entities to pre-position antiviral drugs in or near remote and isolated communities; conduct surveillance; coordinate communication efforts and public health advice; and determine sequencing for H1N1 vaccination.

Canadian provinces and territories in partnership with the Public Health Agency of Canada were responsible for monitoring the emergence and spread of pandemic H1N1 within Canada. In an unprecedented move, public health professionals and decision-makers enlisted mathematical epidemiologists to combine expertise and contribute to the development of effective responses during this pandemic. Presentations and follow-up discussions highlighted an important role for mathematical modelling in organizing and synthesizing data from a variety of sources, identifying gaps in information and prioritizing important areas of uncertainty that should be targeted for further research and data gathering related to pandemic planning and response. Reflecting on the experience gained from responses to the 2009 H1N1 pandemic, experts also shed light on the process of decision-making under uncertainty, and provided critical insights into modelling frameworks that can inform health policy decision-making.

Discussion session

Several issues were raised during presentations with regard to Canadian pandemic planning and its underlying assumptions,⁹ which provided a framework for in-depth discussion from different perspectives in modelling, public health policy formulation and practical implementation.

Surveillance and epidemiology

There is a wealth of knowledge in epidemiology and influenza infection control from both previous pandemics and seasonal epidemics. However, surveillance activities, particularly during the early stages of the pandemic, were not optimally organized to provide the information needed for pandemic response as quickly as possible. There were discrepancies and deficiencies in terms of data collection and surveillance activities in Canadian provinces, which influenced the decision-making process in several ways. While planning assumptions were based on the knowledge and experience gained from past pandemics and seasonal

epidemics, the H1N1 pandemic virus required the creation of new knowledge in the face of limited clinical and epidemiological data. Although efforts were made to provide estimates of the transmissibility, population incidence and other pertinent disease parameters,^{8,15} important information (e.g., age-specific attack rates, susceptibility of populations and sub-populations, and individuals' vulnerability and risk factors) was missing or not available in a timely manner. The lack of a systematic way to generate such information was evident in surveillance activities.⁸ There is a strong need to develop standardized procedures and linkable databases across the country with a more advanced capacity to collect and analyse large-scale data sets, which can then be used to build mathematical models for forecasting, guidance of resource utilization and maintenance of surge capacity in the face of an emerging epidemic.^{3,4}

The H1N1 pandemic represented an urgent situation and required difficult decisions over short timelines with many unknown parameters of disease transmission and control. Now that the second wave of pandemic H1N1 is over, we need to move forward and re-evaluate the available data and information resources using scientific evidence¹⁶ to generate important new knowledge and refine existing knowledge that can be applied for future planning.

Antiviral drugs

While antiviral strategies were generally followed as outlined in the antiviral annex to the national pandemic plan¹⁷ during the pandemic, adjustments were made according to circumstances as new information evolved. Early in the pandemic, the Public Health Agency of Canada¹⁸ modified the existing recommendations in the plan for use of antiviral drugs to include treatment of moderate to severe cases and individuals with pre-existing conditions or at risk of developing poor outcomes, but to exclude treatment of mild cases. This approach addressed the antiviral strategy's primary goal of preventing serious morbidity and mortality, based on modelling outcomes and cost-effectiveness studies,¹⁷ while preserving antiviral supply for the second wave. The secondary objective of the antiviral strategy was to prevent societal disruption. However, it was quickly apparent that Canada was unlikely to experience excessive societal disruption, and therefore addressing this goal was not a significant concern. These strategies were not affected by the sporadic emergence of drug resistance during oseltamivir treatment. Models projected that if widespread oseltamivir resistance had developed,¹⁹ zanamivir would have been recommended as the primary drug and a prioritization framework could have been used for managing the limited stockpiles of zanamivir (sufficient to treat approximately 4% of the Canadian population).

While guidelines for antiviral use were developed nationally,¹⁷ implementation of antiviral strategies varied across

provinces. With the release of the national antiviral stockpile after the first wave, various strategies in provinces and territories were developed to reach individuals with underlying conditions more effectively. Provinces like Manitoba found that antiviral guidelines needed a strong educational component for both the general population and health care providers in terms of seeking medical attention and initiating an early course of treatment. The development of such an educational programme is an essential component of future approaches to antiviral use for seasonal influenza.

Vaccination

Decisions regarding vaccination were difficult, in part because of limited clinical trial information, and ethical and logistical challenges including public acceptability. In Canada, an early decision was taken to purchase adjuvanted vaccine as in Europe but unlike the United States and Australia. The previously described Canadian vaccination sequencing strategy¹⁰ relied heavily on available Canadian epidemiology about risk groups and also incorporated best projections from commissioned modelling.²⁰ The sequencing recommendations focused on preventing severe morbidity and mortality in the population by prioritizing individuals at increased risk of severe disease. Canada's vaccination strategy differed from that implemented in the United States that also prioritized school children,²¹ a strategy which was also informed by modelling literature.^{22–25}

Logistical barriers to a timely vaccine distribution were encountered by provinces and territories. For example, British Columbia experienced an earlier onset of outbreaks during the second wave of the H1N1 pandemic than did other provinces, and questioned whether they should have been allocated vaccine earlier than less-affected provinces. However, vaccination is most effective in preventing the spread of disease when implemented before the start of outbreaks, as during seasonal influenza epidemics, which argues for prioritizing vaccine delivery to provinces with later onset of the second pandemic wave. Although models proved to be useful tools for predicting and evaluating the effectiveness and cost-effectiveness of pandemic vaccination in Canadian settings,^{20,26,27} further investigation is needed to combine modelling and operations research to address target areas for optimal resource allocation within the context of limited vaccine supplies. This calls for the development of novel modelling approaches that can identify the most efficient way of vaccine delivery in different jurisdictions.

Other mitigation strategies

In addition to antiviral therapy and vaccination, other mitigation strategies (e.g., infection control practices, social distancing and school closures) may be useful during pandemic outbreaks.²⁸ Compared to seasonal influenza

epidemics in Canada, there were relatively few healthcare institutional outbreaks of pandemic H1N1 in 2009. This was likely attributed to pre-existing immunity in the population, and particularly the elderly.^{29,30} Other potential reasons for the small number of outbreaks in long-term care facilities include active surveillance of residents, prompt initiation of droplet/contact precautions, and improvements in hand and respiratory hygiene measures.³¹ However, the effectiveness and costs associated with such measures remain undetermined and should be addressed through modelling frameworks that integrate economic components of infection control policies in management of institutional outbreaks.

While modelling projects benefits of community-based control measures,^{32,33} in particular school closures,^{34,35} only one has considered the downstream economic costs associated with such closures, which are extremely large (approximately US \$2700 per capita).³⁶ In the light of the mild nature of the H1N1 pandemic and potential unintended adverse consequences on those who would be most affected by these measures, neither active nor reactive school closures were supported in the Canadian H1N1 response. Although school closures could diminish contacts between children, and potentially reduce disease transmission in the wider community,²⁸ they may result in redistribution of contacts in the population where school children congregate (e.g., daycare centres, cinemas, churches, food stores, malls and athletic arenas). Parents would need to stay home from work to care for children, which could result in high absenteeism rates and stress to critical services, including healthcare.

Although Canadian guidance around mitigation activities was published in summer 2009,³⁷ each province and territory was responsible for the design and implementation of its community-based measures. However, the lack of consistency in the course of actions taken within provinces and territories attests to the fact that future efforts need to be better coordinated and communicated. Educational programmes should be designed to empower schools and other social organizations to provide informative guidance to the public for prudent adherence to recommended preventive measures. To this end, understanding the severity of an emerging disease and the costs and benefits of community-based measures is imperative, and modelling will be an invaluable tool to identify the type and intensity of interventions required to protect the health of individuals and the population as a whole.

Synergies between modellers and public health

Significant communication channels and collaborations have been established between modellers and public health colleagues following the 2003 SARS outbreak in Canada.^{38,39} Yet, emerging diseases often highlight the existing

gaps in these collaborative efforts. The 2009 H1N1 pandemic underscored the need for bridging these gaps, in particular with regard to the availability and access to data and some other critical information that are essential for model inputs of real-time scenarios. The post-pandemic period presents an unprecedented window for modellers to engage in the ongoing processes within which the Canadian pandemic plan and its annexes will be rewritten, underlying assumptions will be challenged, major questions will be raised, and key strategies will be rethought.

Managing public health crises requires engagement of scientific, administrative and political communities across disciplines.³⁸ This poses a real challenge not just for the public health community to provide data and information, but also for modellers to integrate their efforts into the context of public health and transform models into desktop decision-support tools for policy makers.⁴⁰ Knowledge translation activities are therefore indispensable to overcome the challenges of community health in an interdisciplinary environment by forging strong links between theory, policy and practice.

Statement from the workshop

The workshop demonstrated that *'modelling has become heavily engaged in the public health science, decision making process, and practice'*. It highlighted the tremendous growth in disease modelling capabilities and infrastructure in Canada that continue to bridge the gaps between public health and modelling communities. The meeting also underscored the importance of direct communications between modellers, planners and providers dealing with public health crises. In concluding the workshop, it was recommended that a 'National Task Force' be established to integrate modelling, surveillance, planning and decision-making to overcome the real-time challenges of influenza epidemics. With frameworks established during the 2009 pandemic, knowledge translation activities must be continued during non-epidemic periods to ensure that future modelling capacity will be able to meet ongoing threats of emerging infectious diseases.

Competing interests

The authors declare that they have no competing interests.

Authors contributions

SM summarized and drafted the preliminary version of this manuscript based on presentations and round-table discussions. All the authors have contributed to this manuscript, provided significant inputs, revised and approved its final version.

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