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Meeting Report

Managing public health crises: the role of models in pandemic preparedness

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Background Given the enormity of challenges involved in pandemic preparedness, design and implementation of effective and cost-effective public health policies is a major task that requires an integrated approach through engagement of scientific, administrative, and political communities across disciplines. There is ample evidence to suggest that modeling may be a viable approach to accomplish this task.

Methods To demonstrate the importance of synergism between modelers, public health experts, and policymakers, the University of Winnipeg organized an interdisciplinary workshop on the role of models in pandemic preparedness in September 2008. The workshop provided an excellent opportunity to present outcomes of recent scientific investigations that thoroughly evaluate the merits of preventive, therapeutic, and social distancing mechanisms, where community structures, priority groups, healthcare providers, and responders to emergency situations are given specific consideration.

Results This interactive workshop was clearly successful in strengthening ties between various disciplines and creating venues for modelers to effectively communicate with policymakers. The importance of modeling in pandemic planning was highlighted, and key parameters that affect policy decision-making were identified. Core assumptions and important activities in Canadian pandemic plans at the provincial and national levels were also discussed.

Conclusions There will be little time for thoughtful and rapid reflection once an influenza pandemic strikes, and therefore preparedness is an unavoidable priority. Modeling and simulations are key resources in pandemic planning to map out interdependencies and support complex decision-making. Models are most effective in formulating strategies for managing public health crises when there are synergies between modelers, planners, and policymakers.

Keywords Influenza pandemic, mathematical models, public health policy, antiviral therapy, vaccination, non-pharmaceutical measures.

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Background

Influenza pandemics have historically been devastating to humanity with significant morbidity, mortality, and socio-economic costs.[1] The 1918–1919 pandemic, the so-called "mother of all pandemics,"[2] was responsible for over 50 million deaths among countless infections worldwide. Today, 40 years after the last pandemic in 1968, the world may be on the brink of another major global pandemic, with a toll that could exceed that of the 1918–1919 pandemic.[3] While the nature of the next influenza pandemic cannot be predicted with certainty, the identification of strategies to effectively curtail the spread of disease is an unavoidable priority in responding to this global threat. In light of this, the University of Winnipeg hosted a multidisciplinary workshop on the role of models in pandemic preparedness.[4] The workshop brought together public health experts, key decision makers, and infectious disease modelers to: (i) identify the strengths and weaknesses of mathematical models, and suggest ways to improve their predictive ability that will ultimately influence policy effectiveness; and (ii) provide an opportunity for the discussion of priority components of a pandemic plan and determine key parameters that affect policy decision making.

Model-based policy

The first day of this workshop consisted of several outstanding presentations by modelers with the purpose of forging strong links between theory, policy and practice.

These included evaluations and model predictions for antiviral strategies and their implications for drug stockpiling; the role of population contact networks in the emergence and spread of drug-resistance; targeting influenza vaccination at specific age groups; optimal control of pandemic outbreaks; and the usefulness of non-pharmaceutical interventions in disease mitigation. Dr. Chris Bowman (Institute for Biodiagnostics, National Research Council Canada) presented the findings of two modeling studies for the management of drug-resistance in the population,[5,6] especially when concerning the scarcity of antiviral supplies. These studies suggest that an adaptive antiviral strategy with conservative initial treatment levels, followed by a timely increase in the scale of drug-use, can minimize the final size of a pandemic while preventing the occurrence of large resistant outbreaks. Dr. Bowman emphasized that the strategic use of drugs may involve decisions for rationing of limited stockpiles and prioritizing high-risk individuals, and therefore ethical considerations should be taken into account for maximum protection of community health. A comparative evaluation of antiviral strategies in homogeneous and heterogeneous population interactions was presented by Dr. Murray Alexander (Institute for Biodiagnostics, National Research Council Canada). He underscored the importance of prolonging the effectiveness of antiviral drugs through an adaptive treatment strategy, in particular for heterogeneous community structure in which the wide-spread of resistance is more likely to take place. These presentations also provided a brief overview of some recent studies carried out by Canadian modelers in the subject of pandemic preparedness.[7–11]

Dr. Babak Pourbohloul (Director, Mathematical Modeling, BC Centre for Disease Control) proposed an important question regarding ''a forced marriage'' or ''necessity for integration'' between mathematical models and public health policy. In his summary of the day, Dr. Pourbohloul acknowledged that the talks were very encouraging and pointed towards integration and development of modeling platforms that could inform policy in Canada. He also highlighted the significant progress evident since the first pandemic meeting in Vancouver, 2005, during which very little could be communicated to policymakers regarding the value of modeling perspectives.

Dr. Pourbohloul drew attention to various models presented in the workshop, which attest to the fact that we are not lagging behind the current methodology in Canada, but rather are in the forefront.[5-11] However, the central issue is not this, but integration with public health, which is the approach taken by US and UK colleagues for disease modeling and management. A major drawback for Canadian modelers is the lack of appropriate infrastructure, and this calls for investments from healthcare departments and government organizations that could provide modelers with the impetus to continue development of more realistic models. With regard to models used for pandemic planning, we need to critically evaluate their implications for policy implementation. There are two major reasons underlying this evaluation: first, data are limited and prior to the emergence of a novel pandemic strain, it is not possible to study the epidemiological impact of disease or interventions in a real world environment; second, public health authorities would need to be prepared for all the likely scenarios that could influence the outcome of preparedness strategies. Models, by definition, are not supposed to be perfect; approximations are necessary and predictions are made on this understanding. However, a more important question is how much of the knowledge of Canadian modelers has been employed to support policy decision-making? Is it all based upon experience of other countries? Perhaps in Canada, there has not been much communication between modelers and policymakers and therefore modeling results have not been translated into the context of public health. The time has now come to build a pandemic consortium in Canada to have a unified voice from modelers, and close the gaps with infectious disease experts and public health colleagues.

Dr. Susan Tamblyn (Co-chair, Canadian Pandemic Antivirals Working Group) also emphasized the importance of making progress on linking the modeling with decision making within Canada. These enterprises are still really separate in Canada, whereas the value of modeling groups working very closely with the government and health departments is clearly evident in a few countries. We seem to have this linkage in a couple of provinces in Canada, but it is not elevated to the national level. As planners, they understand that modeling can help formulate pandemic policies; however, the lack of collaboration with Canadian modelers obliged them to turn to outside results from published models. Hopefully, the two groups can work closer together to have beneficial impact with regards to pandemic preparedness. Dr. Tamblyn also expressed her concern about public health questions, which often are not amenable to modeling, and about modeling studies that use unrealistic assumptions and scenarios. Therefore, modelers should also be fully engaged in the process of formulating the questions that policymakers need to address in planning for a pandemic. The point was highlighted by Dr. Ping Yan (Centre for Communicable Disease and Infection Control, Public Health Agency of Canada) that models should be based on realistic assumptions to create fundamental knowledge in all aspects of pandemic research.

On the second day, the workshop comprised several presentations by participants from the public health domain. These included unanswered questions concerning the emergence of novel infectious diseases; understanding the space-time dynamics of influenza spread; influenza mortal-

ity in pandemics and seasonal outbreaks; the impact of global air transportation on the spread of diseases; the role of models in public health planning and decision making; the evolution of pandemic influenza viruses; and the potential for novel means to prevent these pandemics. Dr Julien Arino (University of Manitoba) outlined the objectives of an ongoing data-driven project that aims to draw out the likely patterns of disease spread through the network of all international airports in the world with direct and indirect connections. This investigation can have important implications for heading off a global pandemic, with a particular focus on the optimal allocation of containment resources in the most probable ports of disease introduction and spread in Canada. This presentation was followed by an overview of the Ontario Government's Pandemic Preparedness Plan (Allison Stuart, Assistant Deputy Minister of the Ontario Ministry of Health and Long-Term Care), which provides the most comprehensive provincial plan in Canada, having undergone five iterations developed over a 5-year period. This plan details guidance to local planners and specific strategies for health sector sub-groups (critical care, pediatrics, laboratories, long-term care, persons with chronic diseases, mental health settings), first responders, faith groups, private sector organizations, and First Nations communities. This presentation also included a list of concerns which modeling should address relating to acute care services (e.g., estimated hospital surge capacity for a given jurisdiction during a pandemic); local implementation (e.g., identification of the tipping point when primary care will not be able to meet the 24–48 hour standard of care); and antivirals (e.g., identifying the optimal use of drugs and distribution methods for treatment and prophylaxis to decelerate the spread of a pandemic). Dr. Joanne Langley (Co-chair, Canadian Pandemic Vaccine Working Group) presented a detailed analysis of the potential benefits and uncertainties relating to the standard pillars of pandemic influenza contingency plans, covering antiviral drugs; healthcare delivery planning; vaccines; public health measures; and infection control practices. This included the importance of personal protective equipment such as the N95 mask in the healthcare setting, the need for regular and frequent hand washing, and a risk analysis of potential amantadine resistance. Dr. Langley also stressed the need for ''real time'' modeling to provide a rapid analysis of alternative tactical decisions following the onset of a pandemic. Dr. Mark Walderhaug (Associate Director, US Center for Biologics Evaluation and Research, FDA) discussed a stock-and-flow model used for simulating the impact of an influenza pandemic on the US blood supply. The model assumes that susceptibility to the pandemic virus will be universal; multiple waves of infection can occur and each wave adversely impacts infected communities for 6–8 weeks; and absenteeism may reach as high as 40% during the peak periods. Model simulations for the entire US blood supply were presented, and the need for acquiring detailed data of inter-regional flow of blood was emphasized. These data are essential for projecting various scenarios, including run-out for hospitals despite adequate national supplies and time frames for elective surgery cancellations while the blood supply recovers, which highlight the significant challenges involved in supply distribution.

Dr. Paul Gully (Senior Advisor, World Health Organization) emphasized the fact that models are essential for guiding public health, but may also raise more questions for policymakers. He expressed growing concerns about being able to fulfill the requirements for pandemic containment that come from modeling studies: ''models lead to policy but have to confront political reality''. Previous work suggests that a nascent influenza pandemic can be contained at the source if antiviral therapy for a sizable proportion of affected individuals (80–90%) is accompanied by a rapid implementation of non-pharmaceutical measures (such as movement restriction) over a very short period of time (days to 3 weeks).[12,13] On serious discussions from a political standpoint, Dr. Gully demonstrated the significant challenges involved in building the capacity for a timely response to meet the condition for averting a global pandemic. Despite these challenges, he acknowledged that models are invaluable tools for making assumptions explicit and for best using limited data, highlighting key factors determining policy needs, and providing quantitative predictions.

Discussions of the day were then expanded to the implementation of various strategies from a transmission dynamic standpoint. In their capacity, what models offer should be taken along with other health and economic factors to guide sound public health policies. They are not meant to make decisions on managing public health crises, but rather provide recommendations to policymakers. However, for rapid decision making, one would need to consider the interface between simple, interactive, and relatively complex models that may encapsulate population demographics pertaining to the location of a pandemic outbreak.

Synergies between modelers and public health

Dr. Tamblyn chaired the summary and discussion session of the workshop on day 3, and acknowledged the true interdisciplinary nature of the meeting, enriched discussions, very interesting and relevant presentations, with kudos for planning long health-breaks that allowed for interactions and flow of emerging ideas. She distinguished the meeting as the one that has met its objectives and

provided an opportunity for effective communications between modelers and public health authorities on the subject of pandemic preparedness in Canada.

Dr. Ying-Hen Hsieh (China Medical University, Taiwan) offered his perspectives on the workshop with great potential for expanding collaboration with Canadian colleagues in future work. The meeting highlighted important aspects of Canadian public health that will be useful for creating an effective venue to communicate with public health in Taiwan. Dr. Hsieh, as a prominent modeler in Taiwan, shared his experience with SARS (severe acute respiratory syndrome) and exemplified the opportunities missed by public health to engage modelers: ''by the time they called me in, it was 2 weeks before the end of SARS outbreaks''. In 2005, there was a cabinet agreement to promote an influenza vaccine R&D program in Taiwan, partly for the economic opportunities it offers; he was brought in after the decision was made with the hope that ''modelling results will be in line with government policy''. He depicted that in public health in Taiwan, a highly challenging task has been to establish collaborative efforts, but the important lesson from this workshop is to understand the process of making decisions, identify its key parameters, and determine effective ways to communicate with policymakers.

Dr. Benjamin Ridenhour (US Center for Disease Control) acknowledged that the workshop had been successful in bringing together the communities involved in pandemic preparedness, to share their various viewpoints and expertise in modeling and public health, in a very congenial and friendly environment. The US Center for Disease Control has made substantial efforts to co-ordinate pandemic activities through synergism between public health officials and modelers, which has led to benefits for planning strategies in the United States. As modelers, we need to strengthen our ties to public health, and exploit our potential for developing models that can inform and optimize health policy decisions. This workshop has demonstrated that strong networking is required to adequately prepare for the pressure of real time crises, and cope with surging demands in a pandemic-related emergency.

Concluding remarks

In closing the workshop, Dr. Seyed Moghadas (Institute for Biodiagnostics, National Research Council Canada) valued the time and efforts of participants and appreciated their contributions to the success of this event. Key points inferred from presentations and discussions include:

1. In Canada, the pandemic goals are to (i) minimize serious illness and overall deaths; and (ii) minimize social disruption. Pandemic containment has not been a priority to date and may not be feasible.
2. Development of a pandemic vaccine may take up to 6 months following pandemic detection. However, as novel influenza strains most often emerge in Asia, strong surveillance leading to early detection there can increase our lead time for pandemic vaccine production.
3. Immunization of children can result in significant changes in contact patterns and attack rates. Age is a surrogate for individual behavior that influences pathogen transmission in the population; vaccine efficacy may also vary in different age groups.
4. Antiviral therapy is the cornerstone of the pandemic response in Canada until vaccine is available; however, implementation of the strategy is determined by pandemic planners at the provincial level.

The meeting provided an opportunity for modelers to engage in detailed discussions about modeling strategies that can be employed for gaining new insight into disease processes at the population level and making findings of public health significance. While models serve to synthesize data and suggest optimal scenarios in public health, they can also promote dialogue between modelers and policymakers about alternatives, uncertainties, and assumptions that underlie critical decisions. The workshop revealed that pandemic planning requires involvement of communities across disciplines with firm commitment to the notion that research must ultimately influence policy.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SM, NP, JW, and PY proposed and organized the workshop. 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, and approved its final version.

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