The Modern Crystal Ball: Influenza Forecasting With Mathematical Models

The populations of cities are not laboratory mice, so actions to protect their health often cannot be rigorously tested. But people who are responsible for protecting population health must nonetheless make decisions. At best, those decisions are based on evidence from previous similar events in similar populations, but often this evidence is scanty or not applicable to the situation at hand. That has led to the popularity of mathematical models that simulate populations, allowing policymakers to ask “what if” questions about the interventions that they are considering.

In 2 articles in this issue, Khazeni and colleagues (1, 2) have developed a sophisticated model to examine the health impacts and cost-effectiveness of various influenza mitigation strategies in a city similar to New York for influenza A H5N1 and novel H1N1. The model quantifies the impact of virus epidemiologic features and mitigation strategies on illness and costs—something of interest to us as the New York City Department of Health and Mental Hygiene prepared for fall influenza season. They conclude that expanded use of an adjuvanted vaccine would be the most effective and cost-effective strategy to limit death due to H5N1 influenza. For H1N1, they conclude that vaccinating one third of the population would shorten a pandemic and save more lives if implemented earlier in the season.

Often the greatest utility of predictive mathematical models is not any single conclusion drawn from them but rather their ability to clarify assumptions about the dynamics of disease in a population and to determine which inputs have the greatest impact on the outcome of interest. Policymakers can then focus their attention on the most pressing objective (for example, vaccination or antiviral distribution), and epidemiologists can determine which indicators should most intensively be monitored and studied. For example, Khazeni and colleagues find that the population vaccination coverage required to mitigate spread of H5N1 increases by 10% as vaccine efficacy decreases by 10%. Knowing the dynamics of this relationship is important for policymakers, who can use the information to make decisions on the intensity of resources poured into vaccination campaigns.

Unfortunately, sometimes the inputs that most affect outcomes in models are also subject to the most uncertainty. In Khazeni and colleagues’ model, 2 important inputs with a high degree of uncertainty are the impact of nonpharmaceutical interventions (for example, school closure) and the efficacy of the vaccine. Varying vaccine efficacy dramatically changes the population coverage required to shorten the pandemic; therefore, numerical predictions of the model are only as good as the strength of the assumed value of this variable.

The key to designing the most useful models is that they must weigh the decisions that policymakers will be faced with—and this requires close coordination between modelers and decision makers before and during the situation requiring decisions. Khazeni and colleagues’ model estimates that vaccinating 40% of the population for H1N1 in October could reduce widespread transmission. Vaccinating early and as many eligible people in the population as possible is usually a key goal, but the decision for local health officials often is not what percentage of the population to vaccinate or when to vaccinate—this will depend on the amount and timing of vaccine release, as well as practical barriers to achieving high vaccination coverage. Instead, local public health officials must determine which populations are the highest priorities for vaccination given limited time and resources and whether, if vaccine is not available, any other mitigation measures can substantially decrease infection and death.

Khazeni and colleagues acknowledge that a limitation to their model is the assumption that all members of the population contribute equally to the spread of the disease. In reality, the likelihood of spreading influenza varies substantially across population subgroups. The H1N1 pandemic in New York City from April to July 2009 disproportionately affected school-aged children, who had the highest rate of emergency department visits (3), and studies show that seasonal influenza epidemics peak in school-aged children before they peak in adults (4). For these reasons, school-aged children may be key links in the chain of transmission, and some studies suggest that vaccination efforts focused on this group may mitigate spread in other groups. A Japanese program to vaccinate school children for seasonal influenza in 1977 was associated with a substantial decline in excess influenza and pneumonia deaths in the population (5). Discontinuation of the program in 1994 was associated with a subsequent increase in deaths (5). Another vaccination program in Russia showed a 3- to 4-fold reduction in influenza-like illness among elderly persons after 65% of school-aged children were vaccinated (6).

Despite its limitations, the model demonstrates an important conclusion: The population health benefit of administering even a vaccine of low efficacy (50%) can be substantial if the proportion of the population receiving the vaccine is high. Although heightened public awareness of H1N1 this year and H5N1 in the past few years has increased attention to influenza, vaccination rates for seasonal influenza have been disappointing. Seasonal influenza kills more than 36 000 people every year (7), but fewer than 50% of high-risk adults aged 18 to 64 years received...
a vaccination last year (8). Health care professionals must take advantage of this heightened public awareness to educate and vaccinate a larger proportion of the population, not only for H1N1 this season, but especially for seasonal influenza, which has thus far killed far more people.

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References

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