Multi-scale model for the transmission of influenza using realistic social networks and agent-based model

Dongmin Guo[1], King C. Li[1], Timothy R. Peters[2], Beverly M. Snively[3], Katherine A.Poehling[4], and Xiaobo Zhou[4]
1 Department of Radiology, 2 Department of Pediatrics, 3 Department of Biostatistical Sciences, 4 Department of Epidemiology and Prevention, Wake Forest University School of Medicine, Winston-Salem, NC, USA

Highly pathogenic influenza viruses can spread world-wide and lead to severe economic loss annually. Mathematical models are effective approaches to describe the disease transmission and assess multiple interventions toward it. Current models, however, often suffer two shortcomings: they assume homogeneity among individuals, who in reality are highly heterogeneous; and they seldom consider patients' viral loads, which are critical variables in infectious models. In this paper, we categorize the factors influencing the epidemic into four categories: patients' viral load, individual's immune response, individual's personality, and environment in order to simulate influenza epidemic occurring in a city in the U.S. To integrate these factors, we first build a heterogeneous network to describe the social structure characterizing individuals' interaction in reality. The style and frequency of interactions determine the transmission of influenza. Then, we use agent-based model to describe the internal causes and external causes that influence the individuals' interaction. Demographic information of the city and patients' clinical information are used to train the network and agent-based model. Using this model, we simulate the epidemic in three different influenza seasons, test the efficiency of vaccination and school closure by simulating different magnitude of epidemic, and analyze three critical factors influencing the epidemic. The results show that, in the case without any extra interventions, 91.7% of them revealed explosive growth with an average infection rate of 15% and the basic reproductive number R0 was 1.3. Network degree (average connections every individual) impacts the epidemic mostly. They also show vaccination strategy targeting children and people in workplace helps prevent an epidemic effectively. And school closure can reduce the infection number quickly, implying it is more suitable when the epidemic is server.