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Inferring Influenza Epidemics in the Presence of Stratified Immunity

Authors : Hsiang-Yu Yuan, Marc Baguelin, Kin O. Kwok, Nimalan Arinaminpathy, Edwin Leeuwen, Steven Riley

Abstract : Traditional syndromic surveillance for influenza has substantial public health value in characterizing epidemics. Because the relationship between syndromic incidence and the true infection events can vary from one population to another and from one year to another, recent studies rely on combining serological test results with syndromic data from traditional surveillance into epidemic models to make inference on epidemiological processes of influenza. However, despite the widespread availability of serological data, epidemic models have thus far not explicitly represented antibody titre levels and their correspondence with immunity. Most studies use dichotomized data with a threshold (Typically, a titre of 1:40 was used) to define individuals as likely recently infected and likely immune and further estimate the cumulative incidence. Underestimation of Influenza attack rate could be resulted from the dichotomized data. In order to improve the use of serosurveillance data, here, a refinement of the concept of the stratified immunity within an epidemic model for influenza transmission was proposed, such that all individual antibody titre levels were enumerated explicitly and mapped onto a variable scale of susceptibility in different age groups. Haemagglutination inhibition titres from 523 individuals and 465 individuals during pre- and post-pandemic phase of the 2009 pandemic in Hong Kong were collected. The model was fitted to serological data in age-structured population using Bayesian framework and was able to reproduce key features of the epidemics. The effects of age-specific antibody boosting and protection were explored in greater detail. RB was defined to be the effective reproductive number in the presence of stratified immunity and its temporal dynamics was compared to the traditional epidemic model using use dichotomized seropositivity data. Deviance Information Criterion (DIC) was used to measure the fitness of the model to serological data with different mechanisms of the serological response. The results demonstrated that the differential antibody response with age was present (ΔDIC = -7.0). The age-specific mixing patterns with children specific transmissibility, rather than pre-existing immunity, was most likely to explain the high serological attack rates in children and low serological attack rates in elderly (ΔDIC = -38.5). Our results suggested that the disease dynamics and herd immunity of a population could be described more accurately for influenza when the distribution of immunity was explicitly represented, rather than relying only on the dichotomous states 'susceptible' and 'immune' defined by the threshold titre (1:40) (ΔDIC = -11.5). During the outbreak, RB declined slowly from 1.22[1.16-1.28] in the first four months after 1st May. RB dropped rapidly below to 1 during September and October, which was consistent to the observed epidemic peak time in the late September. One of the most important challenges for infectious disease control is to monitor disease transmissibility in real time with statistics such as the effective reproduction number. Once early estimates of antibody boosting and protection are obtained, disease dynamics can be reconstructed, which are valuable for infectious disease prevention and control.

Keywords : effective reproductive number, epidemic model, influenza epidemic dynamics, stratified immunity
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