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ORIGINAL ARTICLE

Assessment of the Intensive Countermeasures in the 2009 Pandemic Influenza in Korea

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Abstract

Objectives: It is critical to implement effective multiple countermeasures to mitigate or retain the spread of pandemic influenza. We propose a mathematical pandemic influenza model to assess the effectiveness of multiple countermeasures implemented in 2009.

Methods: Age-specific parameters, including the transmission rate, the proportion of asymptomatic individuals, the vaccination rate, the social distancing rate, and the antiviral treatment rate are estimated using the least-square method calibrated to the incidence data.

Results: The multiple interventions (intensive vaccination, social distancing, antivrial treatment) were successfully implemented resulting in the dramatic reduction in the total number of incidence.

Conclusion: The model output is sensitive to age-specific parameters and this leads to the fact that a more elaborate age group model should be developed and extensive further studies must be followed.

1. Introduction

Influenza imposes serious social and economic burden to many countries all around the world [1]. In the US, seasonal influenza results in 200,000 hospitalizations and 36,000 deaths annually, thus its economic burden amounts up to $87.1 billion per year [2]. In France, the economic loss due to the absence from workplace caused by influenza is approximately 13,076 French Francs (about €2,431) in a year [3]. People in UK reportedly miss on average 2.8 workdays because of influenza [4]. In Germany, the per unit cost of an influenza case in 1996—97 was 1,777 Deutsche Mark (about €1,105.63) [5]. According to Szuch [6], the productivity loss per unit due to missing workdays because of influenza was to range from €1,379 to €6,991 and from €482 to €1,409 due to direct infection. In addition to direct economic burden, spread of

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influenza can cause psychological burden that is not reported in the statistical records on economic loss.

Therefore, government and public health officials in many countries have made their efforts to resist against the spread of influenza, which is especially the case when it comes to pandemic influenza. The countermeasure strategy includes vaccination, social distancing, and anti-viral treatment. Given the limited amount of available resources, it is critical to find the most effective strategy or multiple strategies before the influenza takes place. Moreover, it is crucial to assess the effectiveness of these countermeasures afterwards since it would provide invaluable information for the future influenza plan. Mathematical modeling is useful for both aims. Using mathematical models, we can simulate how the epidemic would change when we utilize specific countermeasures. Also, we can calibrate it using empirical data and assess the effectiveness of countermeasures which was implemented in the past. The latter approach is especially conducive when we have only data which includes the impact of a variety of countermeasures [7,8]. Assessing the effectiveness of each countermeasure would increase the possibility that we can handle the influenza more efficiently for the future. It was the case of SARS in 2003 where models were built based on past data and appropriate intervention strategies were implemented based on the predictions that the models produced.

This stud focuses on the case of 2009 Influenza A (H1N1) in the Republic of Korea (hereafter Korea). Influenza A (H1N1), a mutant of swine flu which is known to appear first in Mexico in 2009 and spread to the whole world, has been a serious public health problem as well as social and economic ones throughout the globe [9,10]. In the US, according to CDC, about 600 million people, which amounted up to 20% of total US population, were reportedly to be infected by the influenza. In Korea, after a traveler to Mexico was identified to be infected in April 2009, the number of infected was peaked in November. The Korean health authorities implemented a vaccination program to the hospital personnel from October 27 and expanded the coverage of vaccination to the general public from November 11 [11]. This intervention turned the diffusion trend downward, and the Influenza A (H1N1) was finally declared to be eliminated from Korea in October 2010. The peculiarity of this disease was the high infectious rate of the younger age group and low rate of the older (65 and over) age group [12]. It is believed that the older age group get partially immune when they have experienced Spanish Influenza in the past [13].

As the case above and others show, when it comes to assessing the effectiveness of countermeasures, the age structure of population should be taken into consideration. It is no wonder because people in different age groups can be justifiably assumed to have different health conditions and different contact rates which come from different social and economic behaviors. There have been many previous researches about the effectiveness of countermeasures include age structures into their models [2,14,15,16,17].

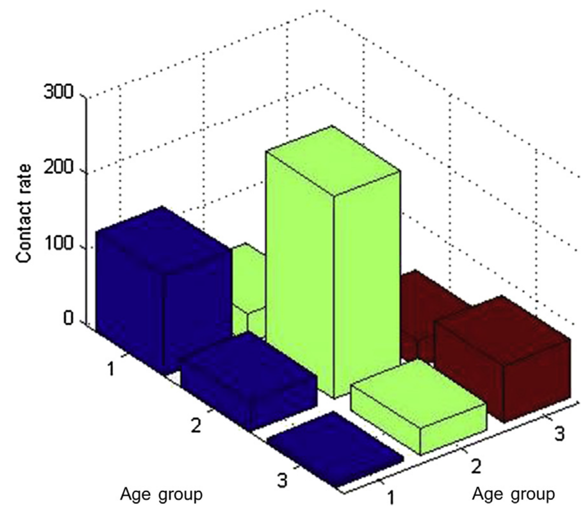

Figure 1. Contact matrix between and within age groups.

This study presents a mathematical model with three age groups of the pandemic of Influenza A (H1N1) in 2009. Also, using the incidence data in Korea, we carry out parameter estimations where the best-fitted parameters are sought by the least-square method. The effectiveness of three intervention strategies, which are age-specific vaccination, social distancing, and antiviral treatment, is compared by calculating the basic reproduction number, R_0.

2. Materials and methods

2.1. Influenza pandemic transmission model with age groups

We integrated the age structure of the Korean population to the influenza transmission model, based on the 2009 Census data [18]. The Korean population was then divided into the following three age groups: Group 1, 0–19 years; Group 2, 20–64 years; and Group 3, ≥65 years. Further, each age group (indexed by i) is classified into eight epidemiological states, namely, susceptibility (S_i), effectively vaccinated but not yet protected (V_i), latent (E_i), symptomatic and infectious (I_i), asymptomatic and infectious (A_i), hospitalized (J_i), recovered (R_i), and dead (D_i). Susceptible individuals in age group i are exposed to the influenza virus at the force of infection:

$$\lambda_i = \beta_i \sum_{j=1}^{3} \varphi_{ij} \frac{bA_j + (1-u_i)I_j}{N(t)}$$

where β_i is the transmission rate of age group i, which is assumed to be constant within age groups. The total population size $N(t)$ is given by: