PREDICTION OF COVID-19 DYNAMIC INDICATORS USING MATHEMATICAL MODELING

Leonid Pisarenko, Sergey Gumenyuk, Sergey Fedotov, Elena Zotova

GBUZ "Scientific and Practical Center for Emergency Medical Aid of the Moscow Department of Health".

Bolshaya Sukharevskaya Square, 5/1, building 1, 129090, Moscow, Russian Federation

E-mail: zotova.e@inbox.ru

Mathematical modeling of forecasting the spread of especially dangerous and highly contagious infectious diseases among the population in a separate territory has been used by scientists all over the world for almost 100 years.

COVID-19 is a completely new viral disease with an overwhelming predominance of many unknown etiopathogenetic, epidemic, clinical and many other characteristics that significantly complicate obtaining reliable prognostic indicators. Now there are dozens of effective mathematical methods for predicting infectious processes using computers and highly intelligent computer programs, each of which has its own advantages and disadvantages due to the presence of certain initial data. Thus, models were developed to predict COVID-19, taking into account the possibility of reinfection (SIS model), death (SIRD), the presence of an incubation period in the disease (SEIR), temporary immunity of children due to maternal antibodies (MSIR), reinfection and the presence incubation period (SEIS), etc.

However, neither the duration of the immunity produced after recovery, nor its resistance remain unknown. There is very little information for the correct calculation of the rate of recovery of patients. Considering that a small number of the population recovers literally a week after infection and a mild course of the disease, then the bulk of the population continues to be ill for a long time and heavily. Therefore, these models have a high predictive error and can be considered as an auxiliary system for basic mathematical calculations.

Among all others, we have recently been studying the possibility of using mathematical modeling of the dynamic epidemic indicators of COVID-19 using S. Ignatiev's method. Let's make a reservation initially that the proposed mathematical model is not final, although it may be useful for obtaining prognostic indicators and making appropriate management decisions.

In this method, a key feature is the division of all patients into two main groups: identified and isolated carriers of infection (ND) and not identified, due to the latent incubation period, which are the carriers of the COVID-19 virus in the population (N_A). The total number of patients (N_T) at a certain date d_i is equal to the sum of the detected and undetected carriers of the infection on the same date:

$$N_T(d_i) = N_D(d_i) + N_A(d_i). \qquad (1)$$

Let us conventionally designate that the average incubation period (t_D) of the disease is six days, therefore, each sick person, on average, six days after infection, asks for help and is isolated, i.e. the total number of detected carriers of the infection on the date d_i is equal to the total number of cases six days earlier:

$$N_D(d_i) = N_T(d_i\text{-}6). \qquad (2)$$

As a result, the number of people infected increases every day. The virus is spread by undetected carriers of infection at a certain rate, which is characterized by a parameter called transmissibility (R_0). Numerically, the parameter is equal to the average number of people that one person infects before isolation, and depends on the density and behavior of the population at different stages of the development of the epidemic. When $R_0 < 1.0$, the epidemic dies out, and vice versa.

ISBN: 978-81-947843-0-2; DOI: 10.21467/abstracts.102

On average, an undetected patient spreads the infection within six days. This means that it infects $R_0/6$ people during the day. If we assume that those who have been ill develop strong immunity, which excludes the possibility of their re-infection, then the total number of those infected on the date di is equal to the sum of the total number of those infected the day before and the number of new infections, which is proportional to the number of not yet detected infected, taking into account the transmissibility of the disease and the proportion already of the infected population:

$$N_T(d_i) = N_T(d_i\text{-}1) + R_0 \times N_A(d_i\text{-}1) \times (1\text{-}N_T(d_i\text{-}1)/N_P)/6, \qquad (3)$$

where N_P – is the total population of a city or country.

By the beginning of the epidemic (date d_0), this is $N_A(d_0)=1$, $N_T(d_0)=1$, and $N_D(d_0)=0$. Therefore, for each subsequent day, the total number of infected patients can be calculated using equation (3), the total number of already identified patients using equation (2), and then the total number of not yet identified infected patients using equation (1).

These equations are presented in discrete, not differential (continuous) form, so for calculations, such a model can be easily reproduced on a programmable calculator or in any spreadsheet editor.

Initially, it seems that the model does not take into account the existence of asymptomatic virus carriers. However, if the proportion of asymptomatic carriers in the population does not change over time, then their presence should be taken into account implicitly by the value of the coefficient R_0. So, if the behavior of the population changes from the date d_1 (for example, due to the introduction of quarantine measures), the parameter R_0 changes its value already from this date, becoming R_1. If the behavior changes again, then a pair of d_2 and R_2 appears, etc.

If we apply this model to analyze the parameters of the spread of infection on average in Russia, then at the initial stage of the development of the COVID-19 epidemic, the transmissibility of the coronavirus was 2.1, i.e. one infected person infected on average a little more than two people. In Moscow, this parameter was slightly higher during this period (R = 2.19), most likely due to the higher population density. At the same time, the introduction of a self-isolation regime in Moscow and other regions of Russia led to a decrease in the transmissibility of the SARS Cov-2 coronavirus to the same value of 1.55, which was not enough to stop the overall development of the epidemic. A responsive response to this indicator was the introduction of access control in Moscow and some other regions. As a result, the transmissibility in Moscow decreased to 1.08, i.e. twice as compared to the initial value of R_0. Nevertheless, the value remained even more than one, which meant the continued accelerated spread of the coronavirus among the population. Since the access regime was not in effect in all regions of the country, in general in Russia the transmissibility was higher than in Moscow and was equal to 1.135.

In practice, all other things being equal (in particular, while maintaining the current observational and quarantine measures), the peak value of the number of detected patients per day could be reached in Moscow by the end of the second week of August within 11,500-12,000 new cases, and in mid-September in in Russia as a whole - 310,000-320000 new cases.

After passing the peak, it will take several more months for the number of newly diagnosed cases to fall to an acceptable level. So, in Moscow, the number of new cases will decrease to 1000 per day only by the end of January 2021, and by the end of the COVID-19 epidemic, only about 15-23% of the population will be infected.

This mathematical model also makes it possible to estimate the probable mortality from COVID-19. So, the total number of deaths on the date d_i is equal to the total number of cases a few days earlier, multiplied by the lethality:

$$N_L(t_i) = N_T(d_i\text{-}t_L) \times L, \qquad (4)$$

ISBN: 978-81-947843-0-2
DOI: 10.21467/abstracts.102

where t_L is the average time from infection to death, found to be 8 days, and L is the lethality, equal to the ratio of the number of deaths to the sum of the number of deaths and recovered (for Russia it is 1.08%).

At the same time, it is necessary to understand that the calculated mortality rate becomes initially overestimated, and the stronger, the fewer asymptomatic and mild cases of the disease are detected.

If you do not introduce observational and quarantine measures, then, while maintaining current conditions, the peak number of deaths in Russia will occur in mid-September and up to October-November (within 3,300 deaths per day), and the total number of losses could reach more than 360 thousand people. Such a negative scenario can be avoided by strengthening quarantine measures and thereby reducing the transmissibility of the virus below 1.0. In this case, the peak incidence will be reached after six days, and the subsequent rate of decline in the detection of new cases of the disease will be the higher, the lower the transmissibility index, i.e. the more severe the measures taken.

Based on the above, we believe that the use of modern methods of mathematical modeling of the COVID-19 epidemic makes it possible to proactively obtain more reliable information about the development of the epidemic process of an unknown and new type of infectious disease both in the defined territory of the settlement, and in the country, and in the event of a pandemic - and several countries. Mathematical modeling of the infectious process of especially dangerous infections is mandatory in predicting and implementing the entire complex of anti-epidemic and treatment-and-prophylactic measures at any stage of their implementation. On the basis of this mathematical model, the emergency medical service was able, in the usual anti-epidemic mode, to make the most of its available capabilities and reserves for providing emergency medical care to the population of Moscow, without attracting additional forces and means for this.

ISBN: 978-81-947843-0-2
DOI: 10.21467/abstracts.102