On the Issue of Assessing the Effectiveness of Air Defense Based on a Pandemic Model

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To assess the effectiveness of quarantine measures during the COVID'19 pandemic and to make recommendations on when to start quarantine, experts from some NATO countries have widely used a pandemic model called the Flat the curve. They are based on the SIR model (Susceptible-Infectious-Recovered) proposed in 1927 by Kermack and McKendrick [1], which describes, using a system of ordinary differential equations, the relationship between the number of people susceptible to infection (S), infected (I) and those already immune to it, that is recovered or dead (R).

Examples of constructing SIR-models for various parameters of epidemic intensity, duration and volume of quarantine measures were obtained by the author (fig. 1) using a computational model of a pandemic posted on the Internet, developed in the R programming language in the Shinty environment (https://tinu.shinyapps.io/Flatten_the_Curve).

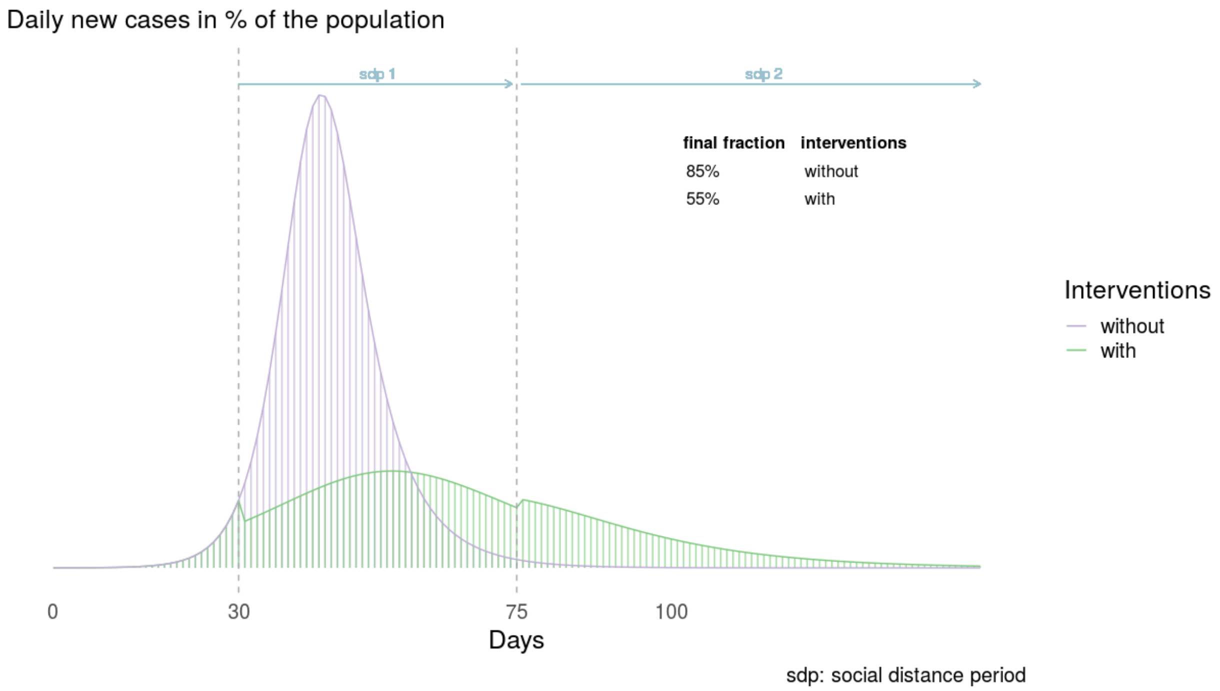

Fig. 1. Flat the curve (https://tinu.shinyapps.io/Flatten_the_Curve).

The versatility of the SIR model lies in the fact that it can be used to assess the effectiveness of systems that resist, within a limited time, a longer exposure to a negative factor. In particular, quarantine measures, for example, physical distancing, shortening the time of interpersonal contacts, and others, can be interpreted in the military field as counteraction by the defending side to the attacking enemy, for example, using air defense forces.

If we draw an analogy between the SIR-curve, which characterizes the number of the infected population, and the damage from attacks by air attack weapons (UAVs) during hostilities, then in the complete absence of air defense systems (similar to the absence of quarantine measures), there would be a maximum peak of destroyed infrastructure in a relatively short period of time.

In the presence of effective air defense, the rate of destruction of objects of protected infrastructure decreases by analogy with the introduction of quarantine for a limited period of time. But later, after the depletion of air defense resources, if the hostilities continue, then a second wave of destruction begins, as is the case with the second wave of the pandemic.

In this case, the SIR-curve of damage will be characterized by a smaller peak due to a decrease in the proportion of previously undestroyed objects. Also, a decrease in the secondary peak is due to the depletion of the resource of the attacking side due to the destruction of air attack weapons in the process of suppressing the active air defense of the defending side (equivalent to the presence of quarantine) and due to the use of other means of destruction by the defending side (air and missile strikes on airfields, ammunition depots, command posts, electronic countermeasures of air attack weapons, etc.).

For a visual interpretation of the intensity factor R_0 used in the SIR model of a pandemic, in relation to assessing the effectiveness of air defense, the following example can be considered. Suppose that each attacking enemy aircraft launches, for example, 4 air-to-ground missiles. In this case, we will assume that each launched missile reaches its target with some probability. This is equivalent to the case of infection by one person to 4 people, that is, $R_0 = 4$.

In the next raid, new attacking aircraft appear, which is analogous to the secondary infection from the infected at the first stage. At the same time, each missile launched at the first stage is replaced at the second stage by a new aircraft with 4 more missiles. There are many such cycles. But sooner or later, the exponential increase in the number of infected (affected infrastructure) will need to be limited. As a result, the model will be equivalent to the case of a decreasing intensity factor R_0 with time.

It should be noted that all pandemic SIR models presented in the public domain had a constant R_0 value throughout the quarantine, while it is necessary to apply a model with an R_0 value decreasing during quarantine measures. This will more adequately correspond to the dynamics of the observed processes.

In medical practice, the R_0 infection rate is considered linear if it is less than or equal to one. This means that one infected person infects only one or one of several people. This option is positive in the end result, since ultimately the virus will not have a human host. On the contrary, R_0 will be exponential if one infected person infects more than one person, and therefore there is a widespread infection, the coverage of which is increasing for a certain number of the population of a country. A similar approach is applicable to various scenarios for the use of air defense forces, the intensity of the use of electronic warfare systems, aviation and artillery of the defending side.

Taking into account the foregoing, it can be assumed that such a concept of modeling the dynamics of combat operations will make it possible to more rigorously assess the effectiveness of an air defense system during an operation or campaign as a whole in comparison with the classical approach based on calculating an estimate of the mathematical expectation of the number of targets shot down in a raid and the prevented damage. This variant of assessing the effectiveness of combat operations can be extended to other types and branches of troops. All this indicates the advisability of military analysts mastering the methodology for modeling pandemics as an alternative approach used to predict the course of hostilities, substantiate scenarios for the use of troops and requirements for their weapons and military equipment. Such approach expands the methodology of identification of the critical requirements for armaments and military equipment [2] in the context of an operational needs statement for defense planning process [3].

References

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