

Mathematical Model of Infectious Disease

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ABSTRACT

In this article, the subject of the mathematical model of infectious disease is presented to students in traditional and non-traditional ways, showing the effectiveness of the methods and the positive results obtained from the groups.

The essence of the problem situation method is to create and solve problem situations in the course of training, based on didactic conflicts used in the organization and conduct of training. Its elimination requires the acquisition of new knowledge, methods, and behavioral skills.

The subject of mathematical modeling of infectious diseases from the subject of mathematical modeling in biology and medicine was conducted in experimental and testing groups of the Faculty of Medical Biology of Samarkand State Medical University 302 and 303.

- The number of students in the first group was 12, and the lesson was conducted in a traditional way.
- The second group, numbering 14 students, was taught the lesson using the "problem situation" method.

Briefly inform the participants about the "problem situation" method

We started our lesson by being 2.

"problematic situation" method A person begins to think and think only when he is faced with problems that are difficult to overcome. Therefore, a well-organized educational problem solving is necessary. The essence of the problem situation method is to create and solve problem situations in the course of training, based on didactic conflicts used in the organization and conduct of training. The main concepts of the problem situation method concept are "problem situation", "problem", "finding a problem", "solving a problem", "conflicts". The first step of the "problem situation" method is the identification of the problem situation, which represents a known or partially understood problem related to the topic under investigation. Its elimination requires the acquisition of new knowledge, methods, and behavioral skills. If the student does not have enough initial information to find ways to overcome the difficulties associated with solving the problem, he will definitely not be able to find a solution to the problem situation, that is, the solution to the problem will not be reflected in his mind. As soon as students accept (understand) the problematic situation, the process of fully understanding the essence of the problem, defining its main relationships, analyzing, summarizing, drawing conclusions and expressing it correctly, based on the complex of knowledge and skills and research experience and thinking, begins. . In this case, the problematic situation becomes a problem that needs to be solved. It is clear from this relationship that every problem manifests a problematic situation, but not all problematic situations become problems. Resolving conflicts is not only a way of scientific knowledge, but also a way of learning, learning, acquiring new knowledge, skills, and skills.

The modeling method is widely used in medicine and related sciences. In medicine, the modeling method is a means of establishing increasingly deeper and more complex relationships between theory and experience. In the last century, the experimental method in medicine began to face certain limits, and it was found that it was impossible to carry out a number of studies without modeling. If we dwell on some examples of limitations in the field of application of experiments in medicine, then they are mainly as follows:

- a) interference with biological systems is sometimes of such a nature that it is impossible to determine the causes of the changes that have occurred (due to interference or other reasons);
- b) due to the low level of development of experimental technologies, some theoretically possible experiments are not carried out;
- c) a large group of experiments related to human experience should be rejected for moral and ethical reasons. But modeling is widely used in medicine not only because it replaces experience.

This is of great independent importance, expressed in a number of advantages:

1. Using the modeling method in one data set, it is possible to develop a number of different models, to choose the most effective one for different interpretations of the studied phenomenon and theoretical interpretation.
2. In the process of creating a model, you can make various additions to the studied hypothesis and simplify it.
3. In complex mathematical models, you can use a computer.
4. Modeling opens up the possibility of conducting modeling experiments (modeling experiments on test animals).

All this clearly shows that modeling performs independent functions in medicine and becomes an increasingly necessary stage in the process of theory creation. In the second half of the 20th century, a science related to medicine, such as immunology, developed widely. Advances in immunology have a direct impact on treatment methods and all clinical practices in medicine. Immunology is closely related to treatment problems (post-operative wound care, organ transplantation, cancer, allergies, and immunodeficiency). Until now, immunologists have collected a lot of data to monitor the progress of various infectious diseases, and based on the analysis of this data, fundamental results were obtained on various levels of detail about the mechanisms of interaction between antigens and antibodies: from the macroscopic to the intracellular genetic. These results made it possible to create mathematical models of immune processes. The simplest mathematical model is based on the equilibrium ratio for each component involved in the immune response. It is because of this concept that the specific features of the immune system are not important for the analysis of the dynamics of the disease, and the main laws of the body's protective reaction come to the fore. Therefore, when constructing a mathematical model, the cellular and humoral components of immunity, which are involved in the fight against antigens entering the body, do not differ. Let's say that the body has such components. They are called antibodies, regardless of whether we are dealing with the cellular-lymphoid immune system or the humoral immunoglobulin.

Antibodies - immunoglobulins are large globular proteins of the blood plasma that are released by the plasma cells of the immune system and serve to neutralize the cells of pathogens and viruses, as well as protein poisons and some other foreign substances.

In this model, it is also assumed that the body has sufficient resources of macrophages that use the products of the immune response, as well as other non-specific factors necessary for the normal functioning of the immune system. In this regard, we will limit ourselves to the consideration of three components: the antigen, the antibody, and the antibody-producing plasma cell. Pathogenic bacteria or viruses act as antigens. It should also be noted that the degree of damage to the organ that is susceptible to antigen attack with the disease is of great importance, because it ultimately leads to a decrease in the activity of the immune system. This should naturally be reflected in mathematical models. Thus, we assume that the main active factors of the infectious disease are the following values:

- 1) the concentration of pathogenic breeding antigens $V(t)$;
- 2) concentration of antibodies $F(t)$;
- 3) $C(t)$ concentration of plasma cells;
- 4) relative properties of the affected organ $m(t)$.

Let's move on to building the model equations. The first equation describes the change in the number of antigens in the body:

An antigen is any substance that the body considers to be foreign or potentially dangerous, and which the body normally begins to produce its own antibodies.

$$dV = \beta V dt - \gamma F V dt . \quad (9.1)$$

The first term on the left-hand side of this equation describes the increase in DV antigens during the time interval Δt by multiplication. Naturally, v is proportional to a certain amount of b , which we call the coefficient of multiplication of antigens. The term $g F V D T$ describes the number of antigens neutralized by the coefficient f in the time interval Dt . In fact, it is clear that the number of such viruses is proportional to both the number of antibodies and the number of antigens in the body; g - coefficient.

Antigens are associated with the possibility of neutralization when they meet antibodies. (9.1) with respect to dt , we have:

$$dV / dt = (\beta - \gamma F) V .$$

The second equation describes the growth of plasma cells:

$$dC = aF(t - \tau)V(t - \tau)dt - u(C - C^*)dt. \quad (9.2)$$

The appearance of plasma cells in the first member of the right side,

τ – the formation time of the plasma cell cascade,

a – the coefficient is the probability of an antigen-antibody meeting, the triggering of a cascade reaction and the number of new cells formed. The second term in the second formula describes the decrease in the number of plasma cells due to aging,

u – a coefficient equal to the inverse of their residence time,

C^* – constant level of plasma cells in a healthy body.

By dividing the equation (9.2) by dt , we obtain the following equation

$$dF = pCdt - h\gamma FVdt - u_1 Fdt, \quad (9,3)$$

here

$pCdt$, Dt - formation of antibodies by plasma cells over time;

p – the rate of production of antibodies by one plasma cell; ; $h\gamma FVdt$ - characterizes the decrease in the number of antigens in the time interval Dt - by binding to antibodies;

$u_1 Fdt$ - reduction of the antibody population, here

u_1 - coefficient inversely proportional to antibody decay time. Dividing the equation (9.3) by dt , we get:

$$dF / dt = pC - (u_1 + h\gamma V)F.$$

Let us consider the equation for the relative characterization of target organ damage.

M - defines the characteristics of a healthy body part,

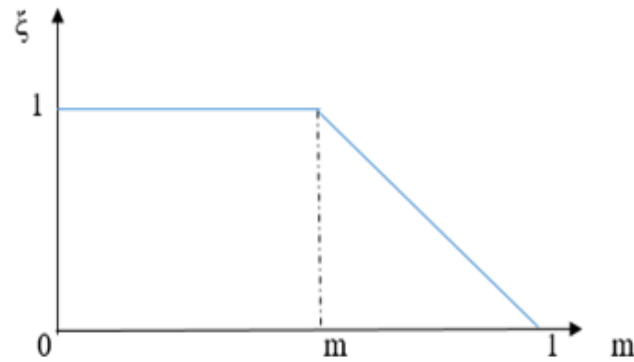
M^* - defines the characteristics of the unhealthy part of a healthy body part.

If we consider the value of M according to the formula

$$m = 1 - M^*/M.$$

This is a relative feature of injury to a healthy body part. It is equal to 0 for an unaffected organ and 1 for completely damaged ones. Consider the following equation for this property:

$$dm/dt = sV - u_2 m.$$



Picture-9.1

In this figure, the curve in the interval $0 < m < m^*$ is equal to 1. This means that the functioning of immunological organs in this interval does not depend on the severity of the disease. But then their performance quickly declines. Thus, we arrive at the following system of nonlinear ordinary differential equations:

$$dV / dt = (\beta - \gamma F) V,$$

$$dC / dt = aF(t - \tau)V(t - \tau) - u(C - C^*),$$

$$dF / dt = pC - (u_1 + h\gamma V)F,$$

$$dm/dt = sV - u_2 m.$$

We attach initial data to the system of equations

$$t = t(0) (V(t(0)), F(t(0)), C(t(0)), m(t(0))).$$

We call the resulting system of equations the simplest mathematical model of the disease. It describes the dynamics of the development of pathogenic infection against the background of the immune response.

This mathematical model can be used to interpret clinical studies

Result: Mathematical model of infectious disease in the first group

The topic was explained in the traditional way and the positive results were obtained.

$$\begin{array}{r} \text{Proportion} \qquad 12 - 100 \\ \qquad \qquad \qquad 1 \quad - \quad x , \\ \hline X=100/12=8,33 \\ 8,33\%*12=99,96\% \text{ assimilation} \end{array}$$

(3 students 5th grade, 4 students 4th grade, 6 students 3rd grade, 1 student 2nd grade) with results.

$$8,33\% * 3 \text{ student} = 24,49\%$$

$$8,33\% * 4 \text{ student} = 33,32\%$$

$$8,33\% * 6 \text{ student} = 49,98\%$$

$$8,33\% * 1 \text{ student} = 8,33\%$$

We achieved a positive rate of 57.81% with 99.96% adoption rate

Unconventional method to students of the second group

The positive results obtained from teaching methods using the "problematic situation" method were consistent.

$$\begin{array}{r} \text{Proportion} \quad 14 - 100 \\ \qquad \qquad \qquad 1 - x , \\ \hline X=100/14=7,14 \\ 7,14\%*14=99,96\% \text{ extension} \end{array}$$



(6 students 5th grade, 5 students 4th grade, 3 students 3rd grade,) with the result.

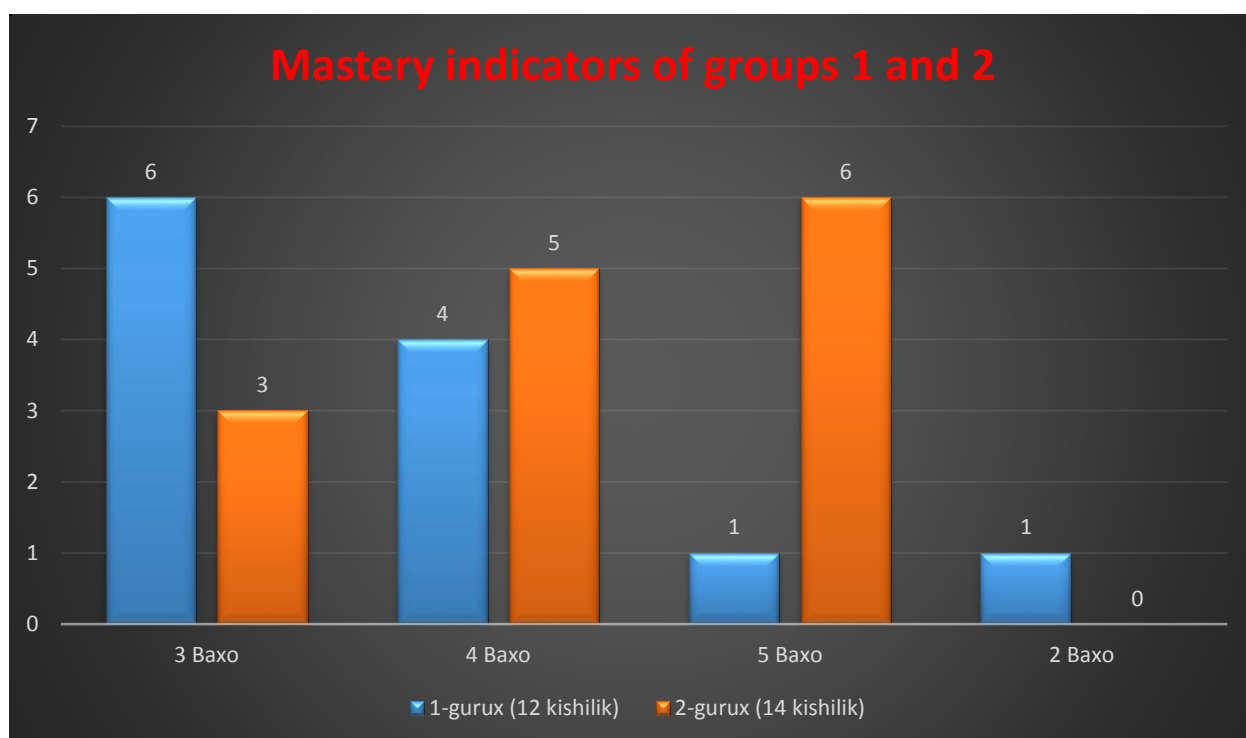
$7,14\% * 6 \text{ student} = 42,84\%$

$7,14\% * 5 \text{ student} = 35,70\%$

$7,14\% * 3 \text{ student} = 21,42\%$

We achieved a positive rate of 78.54% with 99.96% adoption rate

The teaching process using the "problem situation" method gave a good result, because the topic of the mathematical model of an infectious disease is the main cause of the problem, the causes of the disease, the problem, where, with whom, how long ago the symptoms of the disease began to be felt, the symptoms of the disease and other information. we will develop a mathematical model of the disease and achieve quick and effective treatment of the disease.



Conclusion: In the process of using interactive educational methods, we will achieve positive results if we know that the given topic is suitable for the purpose and are ready for it. We inform you that the effectiveness of the lessons learned using the "Problem situation" method was 20.73% higher than the traditional method when experimental tests were conducted in two groups of the Faculty of Medical Biology of the Samarkand State Medical University.

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