SOME ASPECTS OF THE DESCRIPTION OF THE INTERACTION OF VIRUSES WITH THE HUMAN IMMUNE SYSTEM, BASED ON MARCHUK'S MATHEMATICAL MODEL

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Introduction. Viruses are incredibly volatile nowdays and have an ability to adapt to antibiotics, as well as constantly changing its structure and form new strains. That's why Virology is one of the most important areas of research in modern medicine.

The term "infectious disease" means a mapping relationship, established between biocenosis members, where one of them, thanks to pathogenicity mechanisms, can exist in another , and the last one can oppose this pathogenic action. The immune system is one of the main methods of protection against infection.

As is known,immune system response defines the invasion of genetically foreign material (antigen), including the causative agent (pathogen), also its function is to produce the specific objects such asantibodies and NK cells,which able to neutralize or destroy antigens. Based on this, infectious disease can be considered as a conflict between the population of pathogens and the immune system.Therefore, a certain mathematical model, which describes the interaction of viruses with the immune system of the human body, has been developed by the known academician Guri I. Marchuk.

Aim. To conduct a theoretical analysis of the application of mathematical model,designed by the renowned academician Marchuk for describing the interactions viruses with the human immune system.

Materials and methods. In order to solve this problem have been used some theoretical research methods (studying and analyzing the scientific literature to determine the state of development andfor theoretical justification of the research).

Results and discussion..At the time$t = t_0$the initial population of virusesV_0enters the body.Viruses begin to multiplyin the target organ cells,thereby destroying it.Part of the viruses enters the bloodstream, where it interacts with receptors of immunocompetent cells, antibodies, which results in stimulation of the immune system. Plasma cells clones, producing specificto the virusesantibodies, appearin the body after time Ʈ after stimulation. Antibodies bind viruses,and outcome of disease depends on the relative kinetics of these processes. If viruses manage to smite organ enough, then the overall health deteriorates and as a result, immune system function also deteriorates.Antibody production falls, and reduces the likelihood of a favorable outcome.

The model considers the following variables: $V(t)$−concentration ofviruses; $F(t)$ –concentration of antybody (substrates of the immune system that can neutralize viruses: immunoglobulins, receptors of cells); $C(t)$−concentration ofplasma cells – the population ofcarriers and producers of antibodies;$m(t)$−the relative characteristics of the affected organ (the mass, the number of affected cells, etc.);β– antigens replicationfactor,i.e. virus multiplication rate; γ– probability of antibodies to neutralize the antigen.The dynamics of plasma cells affected by the following variables: α – the probability of encountering an antigen-antibody, μ– factor equal to the inverse of life of plasma cells (Index shows the object,for which the variable refers) and etc. The duration of life of antibodies (μ_f) and the rate of antibody production of a plasma cell (ρ) impact on their vital activity.And the organ characterization form such indicators, asμ_m − factor inversely proportional to the time of the collapse of the antibody; σ – the virus constant, different for each disease, etc.This mathematical model is based on a system of nonlinear differential equations:

$$:\begin{cases} V'(t) = \big(\beta - \gamma \cdot F(t)\big) \cdot V(t), \\ C'(t) = \xi(m)\alpha \cdot V(t - \text{Ț}) \cdot F(t - \text{Ț}) - \mu_c \cdot (C(t) - C), \\ F'(t) = \rho \cdot C(t) - \left(\mu_f + \eta \cdot \gamma \cdot V(t)\right) F(t), \\ m'(t) = \sigma \cdot V(t) - \mu_m \cdot m(t). \end{cases}$$

It should be noted, the first equation describes the change in the number of viruses in the bodyand the second describes the dynamics of the plasma cells.The third equation is based on the balance of antibody production processes, their interaction with antigens and natural death. Accordingly, the fourth feature is the relative characteristics of the target organ. In addition, the system is supplemented with initial conditions:

$$V(t_0) = V_0; \quad C(t_0) = C_0; \quad F(t_0) = F_0; \quad m(t_0) = m_0$$

Thus the special attention is paid to the influence of human body temperature.Since the temperature rise acts in two ways: on one side − it inhibits viral replication, and on the other - it increases the catalytic power of enzymes, i.e. antibody production is accelerated. That's why you do not need to take any of antipyretic drugs at the time of illness(Of course, if the body temperature is less than 38.5).

Conclusions. Therefore, the Marchuk’s mathematical model is one of the main models, which are widely used in immunology, virology, epidemiology and vaccination. After all, it can help to trace the formation of acute and chronic disease processes, clarify the role of temperature effects, to examine the conditions of occurrence of complicated forms of the disease.