THE NEW METHOD OF BLOOD ANALYSIS – ESR-GRAPHY – REVEALS NONLINEAR DYNAMICS IN THE BEHAVIOR OF WHOLE BLOOD OUTSIDE AN ORGANISM

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Recently we have suggested a new test for blood investigation as of a holistic, non-equilibrium, biologically active system. The method represents a development of the widely used diagnostic test ESR («erythrocyte sedimentation rate», or «erythrocyte sedimentation reaction»). In our test the position of red cells/plasma interface is registered for example, each 30 sec that allows to analyze the dynamics of the process of red blood sedimentation. The process of red blood sedimentation turned out to be essentially non-monotonous: red cells/plasma interface moves with numerous accelerations and decelerations. The plots of the dependence of sedimentation rate vs. time of blood indwelling in the pipette (ESR-graphs) reflect the individual features of blood of each particular donor and their changes in the diseased states .

We constructed the devices for automatic ESR-graphy in several blood samples simultaneously. These devices allow to record the ESR-graphs with high precision and over any chosen periods of time. Vertically installed pipettes filled with blood are evenly illuminated with the light-diode sources over the whole height and tranmetted light is received by precise CEDs or the video-camera, coupled to a PC. The device sends information of the position of the boundary between relatively transparent plasma and optically dense blood to the computer each 30 sec or at any other time dwell. The device equipped with video-camera allows to observe all the capillaries in real time at the screen of the monitor. During the experiment it is also possible to observe the progress of blood sedimentation on the on the ESR-graphs which may be called out by an operator. After the experiment ESR-graphs as well as numerical data are stored in the archive and may be printed out at any time.

The results obtained with this equipment demonstrate non-monotonous character of the rate of red blood sedimentation; as well as several macroscopic stages in the whole processes. Amplitude and frequency of oscillations, duration of each stage are characteristic for blood of each particular donor. As data are saved in the data bank, quantitative analysis of them is possible. It allows to register the changes in the ESR-graphs in the course of patients' medical treatment. Possibilities are also open for the development of new diagnostic procedures, such as studies of particular drugs and other factors effects upon blood sedimentation dynamics of a particular person.

Our preliminary results had already revealed several peculiar phenomena in sedimenting blood. First, in many cases the unexpected «negative rates of sedimentation» were registered at the initial stages of the process indicating of the upward movement of a cell pile (Fig. 1). Second, low frequency (3-10 milliHz) oscillations were developing in blood moderately (10-40%) diluted with isotonic solution. While in healthy donors' blood these oscillations were emerging after lengthy «latency» phase (dozens of minutes and more), and they were highly periodic and were lasting for many hours (Fig. 2), in patients' blood oscillations emerged much faster, sometimes immediately (depending on the disease ethiology and the gravity of a person's state), they were more chaotic and disappeared earlier.

The nonlinear dynamic behavior of blood is hardly explained in the frame of standard models describing the process of erythrocyte sedimentation in whole blood as a combined effect of sedimentation of individual cells and of their aggregates in the viscous medium. The phenomena of «negative rate of sedimentation» and rhythmic oscillations of the interface urge us to reject standard models based on the Stocks law. The behavior of sedimenting blood reflects, on the one hand, mutual interactions of red cells that associate in a 3D-network constructed of the so called «ruleaux» or «piles of coins» threads. Breaking down or shrinking of several or even one thread should be followed by a cascade of collapsing of several other threads, and this is observed as a downfall event of the interface. Then the system may rest for some time in a quasi-stationary state before the new cycle evolves. From this point of view the «negative rate of sedimentation» may be tentatively explained as the network swelling. On the other hand, white cells, as some of our observations suggest, also play a significant role in dynamic process. White cells need oxygen for their survival, and erythrocytes are the only oxygen source under the condition of ESR measurements. The major part of white cells is normally located at the top of the red cell pile, but as our observations show they from time to time immerse into the red cell mass, «breath» there and again dissociate from erythrocytes. Highly periodic dynamics in the healthy donors' blood shows that white and red cells interactions are well organized. Under pathological conditions this organization is distorted to a more or less extent. We suggest that the process of blood cells sedimentation reveals the active reaction of blood, as a surviving tissue, upon such stress factors as hypoxia, hypodynamia, action of gravitation, contact with the alien surface of glass. The parameters of this reaction depend upon the metabolic potential of blood, the functional state of all is cellular and plasma elements, and in a complex they reflect the physiological state of the individual. Thus, ESR-graphy may provide significantly more information of patients' state than the usual ESR test. Studies of blood sedimentation dynamics will allow also to get better understanding of the physiological as well as of physical-chemical processes that take place in blood – a surviving tissue outside an organism.

Figure 1. An Example of "Negative Sedimentation Rate"

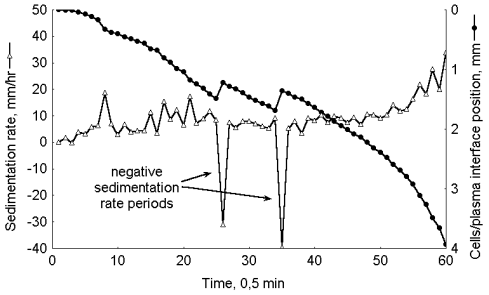

Figure 2. Blood Sedimentation Dynamics for blood/saline = 2/1 (healthy donor)