FLOW POTENTIAL OF THE RABBIT AORTA

Yu. A. Ermolaev and R. A. Markosyan

UDC 612.133:612.115

The fow potential of the rabbit aorta during perfusion with Tyrode solution at the rate of 3.1 ml/sec was -2.21 ± 0.24 mV. Reducing the perfusion velocity to 2.27 ml/sec led to a decrease in the flow potential of the isolated segment of the aorta to -0.76 ± 0.08 mV. The ending of perfusion of the segment of the aorta was accompanied by disappearance of the flow potential. Perfusion of the isolated segment of the rabbit aorta with Tyrode solution containing thrombin (0.8 mg/ml) reversed the sign of the flow potential of the aorta, which now became 0.7 ± 0.35 mV.

The normal course of the processes of blood clotting is largely dependent on the biophysical characteristics of the vessel wall and of the moving blood [2, 7].

The formation of a thrombus in the blood stream is connected with electrochemical processes taking place at the intima–blood boundary, the course of which is determined by the structure of the double electrical layer [6, 8].

A double electrical layer arises at the boundary between two phases of different chemical structure and is connected with the passage of electrically charged particles from one phase into the other, causing the formation of charges equal in magnitude but opposite in sign on the surface between the phases.

The structure of the double electrical layer can be judged from changes in the ζ-potential (the potential difference between the diffuse and adsorption parts of the double electrical layer), the magnitude of which is determined experimentally by electrokinetic methods. One of the methods used to determine the value of the ζ-potential is measurement of the flow potential arising during movement of phases along the surface of separation. The ζ-potential is determined from the flow potential by the equation:

$$\zeta = 4\pi\eta . KE/DP,$$

where ζ is the ζ-potential; η the viscosity; K the specific conductance of the electrolyte; E the flow potential; D the dielectric constant of the electrolyte; P the difference in pressure between the measuring electrodes.

In the investigation described below the effect of the velocity of perfusion with Tyrode solution and thrombin solution on the flow potential of an isolated segment of the rabbit aorta was studied.

EXPERIMENTAL METHOD

An isolated segment of the thoracic aorta of a rabbit, about 25 mm in length, was placed in a special chamber and perfused with Tyrode solution (Fig. 1) at the rate of 3.1 and 2.27 ml/sec. The flow potentials were recorded with the aid of glass microelectrodes with a tip 7-10 μ in diameter, filled with 2.5 M KCl solution and with an intrinsic electrode resistance of 10-15 MΩ. Microelectrodes were inserted into the inner lumen of the segment of the aorta by means of a micromanipulator with interelectrodistance of 10 mm. The microelectrodes were connected through a salt bridge filled with 2.5 M KCl solution, with thallium chloride electrodes, and then to an electronic millivoltmeter. Before the experiment began the instrinsic interelectrode potential of the measuring electrodes was determined.

Laboratory of Development of Autonomic Functions, Scientific-Research Institute of Child and Adolescent Physiology, Academy of Pedagogic Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR A. M. Chernukh.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 77, No.2, pp. 6-8, February, 1974. Original article submitted February 9, 1973.

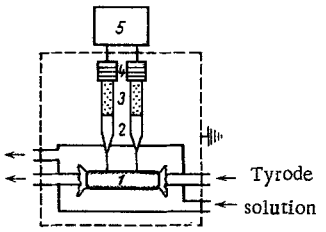

Fig. 1

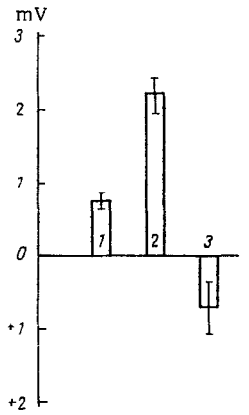

Fig. 2

Fig. 1. Scheme of experiment to study flow potentials of the isolated vascular segment in vitro: 1) segment of rabbit aorta; 2) microelectrodes; 3) salt bridges with 2.5 M KCl solution; 4) thallium chloride electrodes; 5) millivoltmeter.

Fig. 2. Effect of rate of perfusion and addition of thrombin to solution on flow potential of isolated rabbit aorta: 1, 2) perfusion with Tyrode solution at rates of 2.27 and 3.1 ml/sec, respectively; 3) perfusion with Tyrode solution with thrombin.

The thrombin solution was prepared by diluting 0.2 g dry thrombin (Kaunas Bacterial Preparations Factory) in 250 ml Tyrode solution. Perfusion of the aorta with the thrombin solution was carried out at the rate of 3.4 ml/sec. In all the experiments the pH of the perfusion solutions was kept at the same level.

The results of the 26 experiments were subjected to statistical analysis by determining the significance of the mean shifts.

EXPERIMENTAL RESULTS

The flow potential of the isolated segment of aorta during perfusion with Tyrode solution at the rate of 3.1 ml/sec was -2.21 ± 0.24 mV. Reducing the velocity of perfusion to 2.27 ml/sec caused a marked decrease in negativity of the flow potential of the segment of aorta to -0.76 ± 0.08 mV ($P < 0.001$). Stopping perfusion of the aorta with Tyrode solution led to disappearance of the electric flow potential and in that case only the intrinsic interelectrode potential of the measuring electrodes was determined.

Perfusion of the segment of aorta with Tyrode solution containing thrombin in a concentration of 0.8 mg/ml reversed the sign of the flow potential of the aorta to positive with a value of 0.70 ± 0.35 mV ($P < 0.01$) (Fig. 2).

The presence of high negative electric charges on the outer side of the membranes of the blood cells and intima of the blood vessels is now firmly established; it may be a condition of stabilization of the fluid state of the blood [1, 2, 4, 5, 7].

A decrease in the negative charge of the vessel wall may disturb the normal course of blood coagulation and may be an important triggering factor in the development of thrombotic complications.

In the present investigations a decrease in the rate of perfusion of the aortic segment reduced the absolute value of the flow potentials, thus demonstrating a change in the ζ-potential of the vessel wall, the magnitude of which reflects the overall density of the surface charge formed at the boundary between the intima and Tyrode solution (blood) [8].

Consequently, a definite correlation exists between the rate of flow of the blood and the bioelectrical characteristics of the vessel wall. One cause of the greater frequency of thrombosis in the distal segments of the vascular system may be the low negative charge on the vessel wall, linked with a decrease in the velocity of the blood flow in those vessels.

Experiments with perfusion of the segment of the aorta with thrombin solution showed yet another possible mechanism of its thrombogenic effect, namely: the effect of thrombin on the sign and magnitude of the electrokinetic potential of the vessel wall. The cells of the vascular endothelium evidently adsorb thrombin on their surface; this leads to changes in the structure of the double electrical layer formed at the boundary dividing the phases of the intima and blood, and to corresponding changes in the electrokinetic characteristics of the vessel wall. The decrease in the ζ-potential and the change in its sign to positive presumably facilitate processes of intravascular thrombosis, while an increase in the density of the surface charge of the vessel wall tends to prevent thrombosis.

LITERATURE CITED

1. B. I. Kuznik, V. F. Rusyaev, and V. P. Mishchenko, Dokl. Akad. Nauk SSSR, 182, No. 2, 480 (1968).
2. A. A. Markosyan, G. M. Levkova, and A. K. Chepurov, in: Proceedings of the Second Conference on Physiology, Biochemistry, Pharmacology, and Clinical Applications of Heparin [in Russian], Moscow (1968), p. 138.
3. A. A. Markosyan and A. K. Chepurov, Fiziol. Zh. SSSR, No. 10, 1451 (1970).
4. D. A. Rubinshtein, General Physiology [in Russian], Moscow (1947).
5. H. A. Abramson, J. Gen. Physiol., 12, 711 (1929).
6. P. N. Sawyer, E. E. Suckling, and S. A. Weselowski, Am. J. Physiol., 198, 1006 (1960).
7. P. N. Sawyer, S. Srinivasan, P. S. Chopra, et al., J. Biomed. Mat. Res., 4, 43 (1970).
8. S. Srinivasan and P. N. Sawyer, J. Micromol. Sci., 3, 545 (1970).