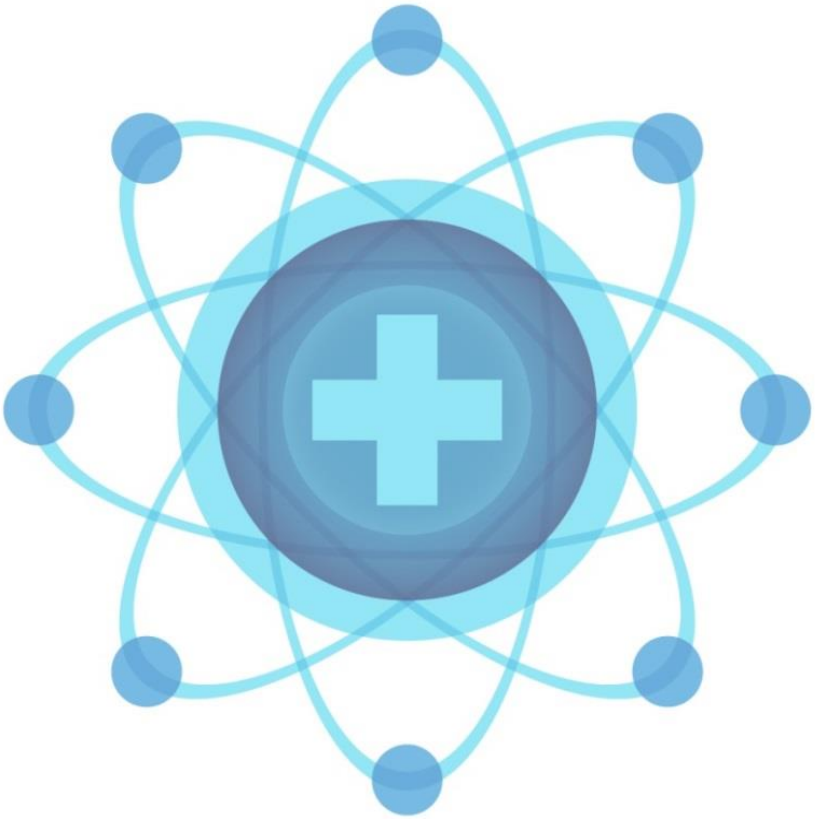

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Changes in dynamic blood viscosity and biophysical properties of erythrocytes in experimental hydronephrosis

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Abstract: Purpose: to evaluate the dynamics of changes in the rheological properties of blood and the biophysical properties of erythrocytes during the development of hydronephrosis. **Materials and methods of research:** Experiments were carried out on 82 mature male rats weighing 180-200 g. Stolyar's micromethod was used to determine the EFP of erythrocytes. The principle of the method is that in a specially designed Goryaev chamber, using a stopwatch, the speed of movement of each erythrocyte in an electric field created by silver electrodes is measured under a microscope. The speed of 15 erythrocytes in different directions is measured. **Results:** In contrast to all previous terms of the experiment, the 7th day of the experiment was characterized by a sharp change in almost all the studied rheological parameters, with the exception of EPME. The latter by this time became equal to 99.16±4.66 mW, which is 17.8% higher than the norm. And the value of EPPE was equal to 0.62±0.09 /sec/ v /cm, which is more than 2 times less than the values of intact animals. Accordingly, the "zetta" value of the erythrocyte membrane potential also decreased, amounting to 10.9 ± 0.22 mW, which is 42.87% lower than the corresponding indicator of the intact group. **Conclusions:** Pronounced violations of the properties of the system of biomembranes, identified by us on the example of erythrocyte membranes and rheological properties of blood on the 7th day of the experiment, in our opinion, are an indicator of exhaustion, a breakdown in compensatory reactions of the body and an indicator of the irreversibility of the process.

Keywords: Hydronephrosis, microcirculation, rheology .

Introduction One of the integral characteristics of microcirculation that significantly affects hemodynamic parameters is blood viscosity, especially at the level of the microcirculatory link of the circulatory system, accompanied by the progression of any disease. This is due to the architectonics of the microvascular bed, which provides the greatest resistance to blood flow [3]. The kidneys are a vascular organ, since with a mass of 0.3-0.5% of the total body weight, up to 20% of the minute blood volume flows through them [2]. Despite the importance of the rheological properties of blood to ensure both the functional activity and the metabolic and energy needs of the kidneys, the role of rheological disorders in the hydronephrotic transformation of the kidneys remains poorly understood. In our opinion, the study of blood viscosity will allow not only to understand the mechanisms of development of microcirculatory disorders in hydronephrosis, but also to improve the efficiency of correction of rheological disorders, ensuring the urinary function of the kidneys and their metabolic protection in conditions of impaired microcirculation in hydronephrosis.

The purpose of the work is to evaluate the dynamics of changes in the rheological properties of blood and the biophysical properties of erythrocytes during the development of hydronephrosis.

Materials and methods of research

The experiments were carried out on 82 mature male rats weighing 180-200 g, which, depending on the conditions of the experiment, were divided into groups: intact; sham-operated (laparotomy with separation of the right kidney from the pararenal tissue without ligation of the ureter); rats in which hydronephrosis was modeled by ligation of the right ureter (Iriskulov B.U., Shorakhmedov Sh.K., 1993).

For the normal performance of the formed elements (erythrocytes) of their functions, they must be separated, i.e. be at some distance from each other. This is provided by the electrical charge of the erythrocyte membrane - the zetta potential (the electrokinetic potential of the cell). An indicator of the "zeta" potential is the electrophoretic velocity of the cell [6].

We used Stolyar's micromethod to determine the EFP of erythrocytes [4]. The principle of the method is that in a specially designed Goryaev chamber, using a stopwatch, the speed of movement of each erythrocyte in an electric field created by silver electrodes is measured under a microscope. The speed of 15 erythrocytes in different directions is measured.

EFP of erythrocytes was calculated by the formula:

$$U = \frac{S}{t * H} \left(\frac{\text{мкм}}{\text{с} * \text{в}} \text{см}\right)$$

where U is the erythrocyte mobility
S is the distance over which the studied erythrocytes have moved
t - time in sec
H - potential gradient

"Zetta" potential was calculated using the formula:

$$Y = \frac{4 * \Pi}{HD} * U \text{ (вольт)}$$

where U is the viscosity of the medium
P - Pythagorean number
D is the dielectric constant of the medium

On the 1st, 3rd, 5th, 7th. On days 14 and 30 after ligation of the right ureter, blood was taken from the subclavian vein and examined immediately. Processing of the results obtained was carried out according to the method of variational statistics of Student-Fisher.

Research results

On the 3rd day of the experiment, the membrane parameters tended to some normalization of the disturbed properties. Thus, the EPME index was equal to 110.6±5.1 mW against the indices of the intact group 84.35±4.08 mW. EPPE by this period became equal to 1.14±0.12 /sec/y/cm, and the "zetta" potential was 14.7±0.62 mW, which is respectively 16.2% and 24.2% lower than in the intact group. On the

part of the viscoelastic properties of the blood, some normalization of the values of the shear rate and dynamic blood viscosity was noted. Unlike the previous period, the blood shear rate in the area of the minimum pressure applied to the blood flow was increased by 12.8%.

The electrical properties of erythrocyte membranes in the group of sham-operated animals were as close to normal as possible by this time of the experiment. For example, the blood flow shear rate was 10.13 ± 0.16 in the zone of the minimum c^{-1}, and 64.24 ± 4.78 in the zone of the maximum pressure applied to the blood flow c^{-1}, which practically did not differ from the indices of intact animals. Accordingly, the dynamic viscosity of the blood also changed.

Unlike all previous periods of the experiment, the 7th day of the experiment was characterized by a sharp change in almost all the studied rheological parameters, with the exception of EPME. The latter by this time became equal to 99.16±4.66 mW, which is 17.8% higher than the norm. And the value of EPPE was equal to 0.62±0.09 /sec/ v /cm, which is more than 2 times less than the values of intact animals. Accordingly, the "zetta" value of the erythrocyte membrane potential also decreased, amounting to 10.9 ± 0.22 mW, which is 42.87% lower than the corresponding indicator of the intact group. Membrane disorders, in our opinion, largely determine the violations of the viscoelastic properties of blood. A distinctive feature of this period was pronounced changes both in the zone of low and in the zone of high pressure applied to the blood flow. The shear rate at the minimum value of the applied pressure was 5.01 ± 0.13 c^{-1}, and at the maximum value 38.17 ± 1.95 c^{-1}. These indicators are lower than those of the intact group by 54.7% and 60.6%, respectively. The blood viscosity at minimum and maximum pressures increased according to changes in shear rate.

On the 14th day of the experiment, the previously identified abrupt changes in membrane properties and dynamic shifts tended to some normalization. Thus, compared with the 7th day of the experiment, the EPME decreased by another 10.3% and amounted to 89.9±3.73 mW, which is only 5.4% higher than the value of the intact group. The EPPI increased by 41.9%, and the value of the "zetta" of the potential became equal to 13.2±0.81 MW, which is 21.1% higher than the same indicator in the previous study period. The viscoelastic properties of the blood also tended to normalize. The rate of blood shift at the minimum value of the applied pressure was 6.4±0.18 c^{-1}, and at the maximum value - 51.09±2.63 c^{-1}, which is 27.7% and 41.2% higher, respectively, than in the previous study period.

The 30th day of the experiment was characterized by the continuation of the normalization of the disturbed parameters of the rheological properties of the blood. EPME, EPPE and "zetta" potential of the erythrocyte membrane compared with all previously studied periods were as close as possible to the indices of intact groups of animals. So, EPME in this period of the experiment was equal to 81.2 ± 5.63 mW, and EPME was 1.26 ± 0.08 / sec / v / cm, and the "datt" potential was 17.6 ± 1.01 mW, which less than the indicators of the intact group by 3.7%, 7.4% and 9.3%, respectively. The shear rate of blood flow and dynamic viscosity also reached the maximum values.

Indicators of blood shear rate in animals with complete occlusion of the right ureter

Experimental condition and study time	The value of the pressure applied to the blood flow, mm of water. Art.				
	2	4	8	12	16
intact rats	11.05±0.2	19.84 ±0.75	40.63 ±1.62	63.27 ±2.25	91.74 ±6.45
sham-operated rats					
1st	9.83 ±0.17 ***	11.5± 0.26 ***	33.49 ±2.13 *	41.8± 2.2 ***	65.63 ±4.54 **
3rd	10.13±0.16 **	11.15 ±0.22 ***	23.88 ±1.16 ***	33.76 ±1.53 ***	64.24 ±4.78 **
5th	10.38±0.2 *	13.3± 0.43 ***	29.44 ±1.38 ***	49.92 ±2.22 ***	71.65 ±3.11 *
7th	10.63±0.22	15.49 ±0.59 ***	34.99 ±1.83 *	66.08 ±7.22	79.05 ±2.84
14th	10.57±0.38	16.57 ±0.3 ***	37.72 ±2.62	61.57 ±4.01	72.66 ±4.83 *
30s	10.91±0.39	19.86 ±0.18	40.55 ±0.73	69.83 ±2.11 *	86.24 ±6.21
Rats with ligation of the right ureter					
1st	7.49 ±0.22 ***	9.33± 0.17 ***	21.77 ±0.74 ***	39.8± 2.14 ***	74.56 ±6.95
3rd	8.59 ±0.49 ***	12.09 ±0.54 ***	19.19 ±0.92 ***	33.64 ±3.46 ***	48.72 ±2.9 ***
5th	6.8± 0.24 ***	9.1±0 .43 ***	14.5± 0.56 ***	27.23 ±1.43 ***	42.45 ±2.23 ***
7th	5.01 ±0.13 ***	6.03± 0.21 ***	9.71± 0.27 ***	20.81 ±0.22 ***	36.17 ±1.95 ***
14th	6.4± 0.18 ***	7.72± 0.35 ***	10.91 ±0.43 ***	20.44 ±0.72 ***	51.09 ±2.63 ***
30s	10.94±0.28	14.00 ±0.52 ***	21.22 ±0.46 ***	27.19 ±1.11 ***	72.95 ±2.9 *

Note: *-significant compared with the control group (*-P<0.05; **-P<0.01; ***-P<0.001).

In contrast to the experimental group, in the group of sham-operated animals, there was no wave-like change, which was characteristic of the experimental group. In the group of sham-operated animals, the shifts in both the electrical properties of erythrocyte membranes and the indicators of the shift in blood flow and dynamic blood viscosity tended to gradually normalize the disturbed parameters. Moreover, a number of indicators of the rheological properties of blood, such as shear rate,

dynamic blood viscosity are normalized already by the 7th day of the experiment. EPME, "zeta" potential of erythrocyte membranes and EPME by the 3rd day of the experiment did not have a significant difference from the parameters of the intact group.

conclusions

Comparative analysis of data in the experimental and sham-operated group of animals shows the undoubted role of rheological disorders in the pathogenesis of hydronephrotic transformation. Pronounced violations of the properties of the system of biomembranes, identified by us on the example of erythrocyte membranes and rheological properties of blood on the 7th day of the experiment, in our opinion, are an indicator of exhaustion, a breakdown in compensatory reactions of the body and an indicator of the irreversibility of the process. Blood and its components, being the main system that provides homeostasis of both the whole organism and its constituent elements, cannot remain indifferent to damage to any tissue or system. Functional and structural disorders that occur in the kidneys as a result of complete occlusion of the ureter are reflected in the blood system. Because one of the main roles in the transport of substances through the endothelium is played by the state of endothelial cells, their pinocytotic system and the state of the basement membrane. It is known that when the ureter is occluded, the pressure in the pelvis and calyces increases sharply, which is the cause of pelvic-renal reflux. The latter, in turn, lead to the penetration of urine into the perivascular and interstitial spaces of the kidney, which causes disturbances in microhemodynamics. Violation of the normal capillary permeability of the PIC affects the chemical and cellular composition of the blood, causing the above changes. Early detection and correction of rheological disorders, in our opinion, contribute to the strengthening of the compensatory-adaptive capabilities of the renal parenchyma, preventing the occurrence of irreversible changes in the early stages of occlusion.

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