7. S. Furfaro, J. Prosmanne, and H. Bard, *Biol. Neonate*, **57**, 72-76 (1990).
8. F. Halberg, *Ann. Rev. Physiol.*, **31**, 675-725 (1969).
9. D. C. Hillman, Z. Wang, J. Rigatuso, *et al.*, *Biochimica Clinica*, **15**, 151-154 (1991).
10. W. Kasinger, R. Huch, and A. Huch, *Scand. J. Clin. Lab. Invest.*, **41**, 701-707 (1981).
11. P. N. Le Soufe, A. K. Morgan, and L. P. Soutter, *Acta Anaesth. Scand.*, **68**, 91-97 (1978).
12. F. A. Oski and M. Delivoria-Papadopoulos, *Pediatrics*, **48**, 853-856 (1971).
13. F. A. Oski, *Crit. Care Med.*, № 7, 412-418 (1979).
14. W. Severinghaus, *J. Appl. Physiol.*, **21**, 1108-1116 (1966).

Effect of Transcutaneous Irradiation of the Cubital Vascular Bundle with He-Ne Laser on Blood Rheology

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Therapy with low-energy He-Ne laser has been in use for more than 30 years. *In vitro* investigations, experiments on animals, and clinical studies have shown that monochromatic coherent radiation of He-Ne laser (HNL) activates the immune system, the biosynthesis of ATP, RNA, proteins, and prostaglandins, and stimulates cell proliferation [4,15]. These effects have made it possible to use HNL in the treatment of suppurative-inflammatory diseases, trophic ulceration, and gastric or duodenal ulcers [5,6]. In recent years HNL has come into use for the treatment of ischemic heart disease and chronic failure of the arteries of the extremities [8,10]. Here, great importance in explaining the mechanism of the biological effect of HNL on the organism is attributed to vascular reactions and to changes in the blood rheology. Koslov *et al.* [7] showed the stimulating effect of HNL on the microcirculation. According to the data of Aleinikov *et al.* [1], laser treatment blocks the efferent innervation of the vessels, resulting in vasodilation.

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In studies of the effect of HNL on blood rheology Lysov observed a decrease in blood viscosity, increased deformability of erythrocytes, and suppressed platelet aggregation. These results were obtained for intravascular irradiation of the blood with the aid of flexible light pipes [9].

We studied changes in the blood rheology for another method of irradiation, namely transcutaneous. The method is based on the extremely high permeability of living tissue for red light.

MATERIALS AND METHODS

Rapid effects of HNL were investigated, i.e., the blood samples before and immediately after irradiation were compared. A total of 37 procedures of transcutaneous laser irradiation of the blood (TLIB) were performed in 12 patients with acute pneumonia. The source of radiation was a continuous-mode LG-79-2 HNL, power 17 mW. The duration of irradiation of the cubital vascular bundle was 40 min.

Blood viscosity was determined on a Rotovisco-100 rotary viscosimeter (Germany). The osmotic resistance of erythrocytes was studied after Deich. The elastic properties were assessed as the

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TABLE 1. Effect of Transcutaneous Irradiation of the Cubital Vascular Bundle with Low-Energy He-Ne Laser on Blood Viscosity ($M\pm m$)

Experimental conditions	Blood viscosity (centipoise) at a shear velocity (sec^{-1})			
	1	9	30	150
Before irradiation	25.49±1.04	7.48±0.32	5.53±0.18	3.91±0.10
After irradiation	22.42±0.92*	6.55±0.29*	4.84±0.15*	3.46±0.07*

Note. Here and in Table 2 an asterisk denotes reliability at $p<0.05$ vs. the control.

rigidity index (the ratio between the viscosity of the blood at a high shear velocity and the hematocrit).

The intensity of platelet aggregation was measured on an Elvi/840 aggregometer (Italy). Aggregation was induced by solutions of ADP (2×10^{-5} M) and epinephrine (5×10^{-6} M).

RESULTS

The results of the viscosimetric investigations are presented in Table 1. The rigidity index of erythrocytes decreased from 8.67±0.15 to 8.03±0.13 ($p<0.05$), this attesting to improved erythrocyte viscoelasticity.

The results of measurements of the osmotic resistance of erythrocytes before and after irradiation are presented in Table 2.

The intensity of platelet aggregation increased after irradiation: with ADP from 31.0±4.4 to 44.9±5.1% and with epinephrine from 24.6±3.1 to 37.5±4.7%, ($p<0.05$). In 8 cases the aggregation was unchanged, an initially high intensity of aggregation being noted in all these cases.

Thus, our findings show that TLIB has a rapid and reasonably marked effect on blood rheology: it lowers the viscosity at all velocities of displacement, improves the viscoelacticity of erythrocytes and their osmotic resistance, and activates platelet aggregation. These effects, with the exception of the last, play a positive role in the organism. According to Hageman's law, a decrease of the blood viscosity leads to an increase in the volume blood flow rate. In addition, when the viscosity of the blood is low, the general vascular resistance drops, the myocardial load decreases, and the coronary blood flow is enhanced. An improvement of viscoelastic properties of erythrocytes is especially important for the capillary blood flow, since only in the case of a sufficiently high deformability can this cell, with an average diameter of 7.5 μ, pass through the vessel with its 2.5-μ lumen.

With regard to platelet aggregation, its TLIB-induced activation may increase the probability of pathological thrombosis during venous stasis, hypercoagulation, and lesions in the vascular wall.

The effect of electromagnetic radiation on blood rheology has been known since the 50s, but mainly for the ultraviolet range of the spectrum. A large number of studies published on this question attest to a decrease of blood viscosity, improvement of erythrocyte deformability, and suppression of platelet aggregation following ultraviolet irradiation of the blood [3,11,14]. At the same time, it has been established that just a small portion of the blood (some 5%) has to be irradiated to cause rheological shifts in all the circulating blood. For a time, scientists debated which components of the irradiated blood are the carriers of the information causing all the blood to alter. According to different data, this role is played by erythrocyte membrane glycoproteins, platelets, or lymphocytes [12].

The mechanisms underlying changes in blood rheology after irradiation with the red light of HNL are still unclear. Adequate synthesis of ATP is known to be a prerequisite for the deformability of erythrocytes; otherwise, the function of the ion pumps is disrupted and calcium ions start entering the cell. This leads to disturbances of membrane elasticity and to an increase of viscosity inside the erythrocyte. The discovered improvement of erythrocyte elasticity, evidence of which was the reduced rigidity index, may be due to the favorable effect of HNL on the production of energy. Such an effect of HNL has already been described in a number of publications [2].

The decrease in blood viscosity at low shear velocities can be explained only by a decreased

TABLE 2. Changes of Osmotic Resistance of Erythrocytes after TLIB ($M\pm m$)

Experimental conditions	Hemolysis, %				
	0.55	0.50	0.45	0.40	0.35
Before irradiation	0.00±0.00	4.24±0.45	20.66±2.21	46.89±5.13	94.42±3.03
After irradiation	0.00±0.00	3.73±0.18	14.87±0.75*	32.71±1.59*	90.12±3.41

aggregability of erythrocytes. However, the mechanism of this phenomenon demands further study. Erythrocyte aggregation results from the complex process of interaction between the forces of attraction (Van der Waals forces) and the forces of repulsion (due to the negative charge created by the carboxyl groups of sialic acid, which is a constituent of membrane glycoproteins). Evidently, the absorption of the red light energy is attended by a disruption of the specific balance between these forces, i.e., an increase of the forces of repulsion.

The present studies show that transcutaneous irradiation of the blood with red light of HNL improves the blood rheology. Hence, in this respect transcutaneous irradiation is an alternative to intravascular irradiation. On the other hand, transcutaneous irradiation of the blood exhibits a number of advantages: there are no problems of sterilization of the light pipes and of performing venopuncture on sclerotized or poorly marked veins; moreover, the risk of damage to the vessel or its infection is ruled out.

REFERENCES

1. V. S. Aleinikov, I. V. Maksimovich, and V. I. Masychev, *Elektron. Promyshlennost'*, № 4, 72-76 (1988).
2. S. V. Grachev, S. V. Eliseeva, S. V. Egorova, *et al.*, in: *Advances in Laser Medicine and Surgery* [in Russian], Moscow (1991), pp. 149-152.
3. A. E. Gromov, L. V. Potashev, N. P. Nikonchuk, *et al.*, in: The Mechanism of Action of UV-Irradiated Blood on the Human and Animal Organism [in Russian], Leningrad (1986), pp. 207-212.
4. A. B. Denisov, *Pat. Fiziol.*, № 2, 81-84 (1988).
5. G. I. Duzenko, S. A. Bychkov, V. G. Duzenko, and A. I. Tsivenko, *Klin. Khir.*, № 8, 16-18 (1990).
6. R. S. Zemskov and N.F. Gamaleya, *Ibid.*,№12, 17-18 (1984).
7. V. I. Kozlov, F. V. Litvin, and O. A. Terman, in: *The Use of Lasers in Surgery and Medicine* [in Russian], Moscow (1988), pp. 525-528.
8. I. M. Korochkin and D. T. Ioseliani, *Sov. Med.*, № 4, 34-38 (1988).
9. N. A. Lysov, in: *Lasers in Clinical Practice and Research* [in Russian], Kuibyshev (1990), pp. 41-48.
10. V. V. Murashko, A. V. Strutynskii, A. P. Baranov, *et al.*, in: *Abstracts of Scientific-Practical Conference*, Vol.2, pp.80-82.
11. V. S. Savel'ev, N. P. Aleksandrova, E. B. Petukhov, and S. S. Ryabova, *Vestn.Akad.Med.Nauk SSSR*, №1, 12-16 (1981).
12. K. A. Samoilova, S. A. Snopov, K. D. Obolenskaya, *et al.*, *Vestn. Khir.*, № 12, 51-61 (1989).
13. H. Baumler, P. Lerche, H. Scherf, *et al.*, *Stud. Biophys.*, **103**, № 1, 71-72 (1984).
14. G. Frick, U. Frick, and I. Wiedenhoft, *Folia Haematol. (DDR)*, **110**, № 2, 256-267 (1983).
15. M. Tuca, T. Tuida, and E. Perlino, *Biochem. Biophys. Res. Commun.*, **163**, № 3, 1428-1434 (1989).