GENERAL PATHOLOGY AND PATHOLOGICAL PHYSIOLOGY

Changes in Rheological Properties of the Blood After Irradiation with Helium-Neon Laser

V. I. Karandashov and E. B. Petukhov

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny,* Vol. 121, № 1, pp. 17-19, January, 1996
Original article submitted January 6, 1995

The effect of helium-neon (HNL) laser on the rheological properties of the blood is examined *in vitro* and during the treatment of 22 patients with obliterating atherosclerosis of the leg. It is shown that irradiation with HNL *in vivo* induces negative changes in blood rheology which are proportional to the time of exposure. Intravascular and extracorporeal irradiation reduces blood viscosity in the body as a result of dilution of the blood, as is evidenced by the lowered hematocrit, plasma viscosity, and hemoglobin concentration. Presumably, the decrease in blood viscosity accounts for the positive clinical results of laser therapy of patients with chronic arterial insufficiency.

Key Words: *helium-neon laser; atherosclerosis; blood rheology*

There is solid evidence that red spectrum electromagnetic irradiation affects the organism and its cellular and subcellular functions: the synthesis of RNA, collagen, and proteins, the proliferation and release of granules, the membrane potential, energy synthesis, the generation of reactive oxygen species by phagocytizing cells, etc. [1-4]. These effects have exploited used in the treatment of joint diseases, gastrointestinal ulcers, trophic ulcers of the leg, and slow-to-heal and purulent wounds.

Intravascular laser irradiation (IVLI) and extracorporeal laser irradiation (ECLI) have recently begun to be used in the treatment of some diseases (ischemic heart disease, chronic arterial insufficiency of the legs, bronchial asthma, and septic states). A low-energy helium-neon laser (HNL) with an output of about 1 mW is used as the radiation source.

It is believed that the positive effects of IVLI and ECLI result from increased circulation due to modulations of blood rheology: a decrease in viscosity and an increase in erythrocyte elasticity. Here we present our findings on this topic.

Center for Cardiovascular Surgery, Russian Academy of Medical Sciences, Moscow (Presented by N. R. Paleev, Member of the Russian Academy of Medical Sciences)

MATERIALS AND METHODS

The effect of HNL on the rheological properties of the blood was investigated *in vitro*. Freshly collected heparinized blood from the cubital vein was percolated through 3-mm clear plastic tubes at a velocity of 1 ml/sec. The light guide of a 1-mW HNL was clamped to the outer wall of the tube. Rheological parameters were measured immediately after irradiation and during blood storage for 48 h at 20°C.

The effect of HNL on blood rheology in the body was studied during the treatment of patients with obliterating atherosclerosis of the legs using IVLI (10 patients, 36 procedures) and ECLI (12 patients, 42 procedures). The patients were given from 2 to 5 sessions of laser therapy every other day. Intravascular irradiation of the blood was performed with an ALOK-1 apparatus and a light guide inserted into the cubital vein. The exposure time was 40 min. Extra-

0007-4888/96/0001-0013$15.00

corporeal irradiation was carried out using an Izol'da-ELOK apparatus devised by Dr. Yu. V. Popov. In this apparatus, laser radiation with a power of 1 mW was dissipated over the length of plastic tubing of the blood transfusion system. The segment irradiated was 10 cm long. Blood from the cubital vein (150 ml) was collected in a sterile flask containing a preservative. It was irradiated during a 40-min reinfusion.

Blood viscosity was measured in a Low shear-30 rotation viscosimeter at a shear rate range of 1.285-128.5 sec^{-1}. The hematocrit was determined in an Autocrit centrifuge. The erythrocyte sedimentation rate (ESR) and plasma hemoglobin were routinely monitored. Platelet aggregation activity was studied in an Elvi-840 aggregometer using the following platelet-activating agents: ADP (20 μmol/liter, epinephrine (0.5 mol/liter), and ristomycin (1.5 mg/ml).

RESULTS

Immediately after irradiation with HNL, blood viscosity *in vitro* increased by several percent. The hematocrit and ESR remained unchanged. There was no hemolysis. Measurements performed after 2 h showed that the properties of the irradiated blood had not reliably changed, whereas its viscosity and hematocrit had increased. After 24 h, the viscosity of intact blood at a shear rate of 128.5 sec^{-1} had increased 8.3% and the hematocrit had increased 3 v/v%. ESR decreased by 2.7 mm. The viscosity of irradiated blood increased much more (by 26%). The hematocrit increased from 0.46 to 0.7 liter/liter. ESR dropped markedly, and in some cases no sedimentation was observed. Strong hemolysis was documented: the concentration of free hemoglobin ranged from 0.3 to 1.8 mg/ml. Individual variations of these parameters were substantial. After 48 h, the viscosity of intact blood was 19% higher than the original viscosity. The viscosity of irradiated blood was either very high (almost twice the original value) or low due to complete hemolysis.

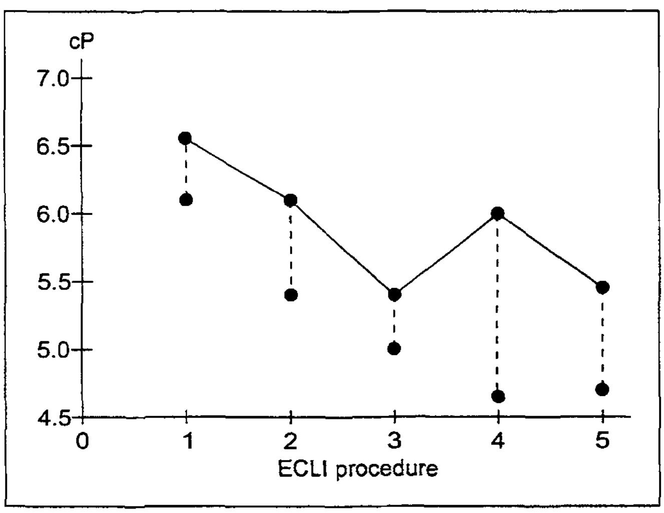

Fig. 1. Changes in blood viscosity (shear rate 128.5 sec^{-1}) during ECLI (a specific example). The broken line shows saturation of blood viscosity immediately after the procedure.

Thus, *in vitro* HNL induces negative changes in blood rheology which manifest themselves not immediately after exposure but during the accumulation of certain damaging factors. It is known that at high shear rates blood viscosity is determined by the number of erythrocytes and their viscosity and elasticity. The hematocrit reflects the number of cells but also their quality. Elastic erythrocytes occupy a much smaller volume than do rigid cells. Since the number of erythrocytes in a vial remains unchanged (unless it decreases due to hemolysis), the increased hematocrit of irradiated blood indicates that an altered packing ability of erythrocytes during centrifugation, which testifies to their impaired elasticity and deformability.

The mechanism underlying the HNL-induced changes in blood rheology is unclear. Since during storage blood viscosity starts to increase growing only after the pool of adenyl high-energy compounds has been depleted, it can be assumed that HNL affects this process. A free-radical mechanism of erythrocyte membrane damage is more probable, since erythrocyte porphyrins have a photosensitizing effect and absorb in the red region of the spectrum.

The following results were obtained when IVLI and ECLI were studied *in vivo*. Immediately after the procedure, blood viscosity decreased 19.87±1.36% at a shear rate of 1.285 sec^{-1} and by 12.56±0.94% at a shear rate of 128.5 sec^{-1} compared with the original value. Plasma viscosity decreased from 1.545±0.034 to 1.425±0.026 cP ($p<0.05$). The hematocrit decreased 3.34±0.33 v/v% with a corresponding drop in the hemoglobin concentration.

Various oscillations of these parameters were observed during therapy. In most cases these oscillations had a steplike nature (Fig. 1). After therapy, blood viscosity decreased from 21.20±2.41 to 16.98±±1.53 cP (shear rate 1.285 sec^{-1}) and from 5.39±0.17 to 4.81±0.15 cP (shear rate 128.5 sec^{-1}). At the end of therapy, the hematocrit dropped from 49.95±1.24 to 46.50±0.93%. All the differences were statistically significant. IVLI and ECLI had virtually the same effectiveness.

Irradiation of the blood with HNL *in vivo* had a strong inhibitory effect on platelet aggregation irrespective of the activating agent (Fig. 2). This effect was observed immediately after the procedure but was transient. Ristomycin-induced platelet aggregation was inhibited to the greatest extent (Fig. 2). There were no significant differences in the effects of IVLI and ECLI on platelet function.

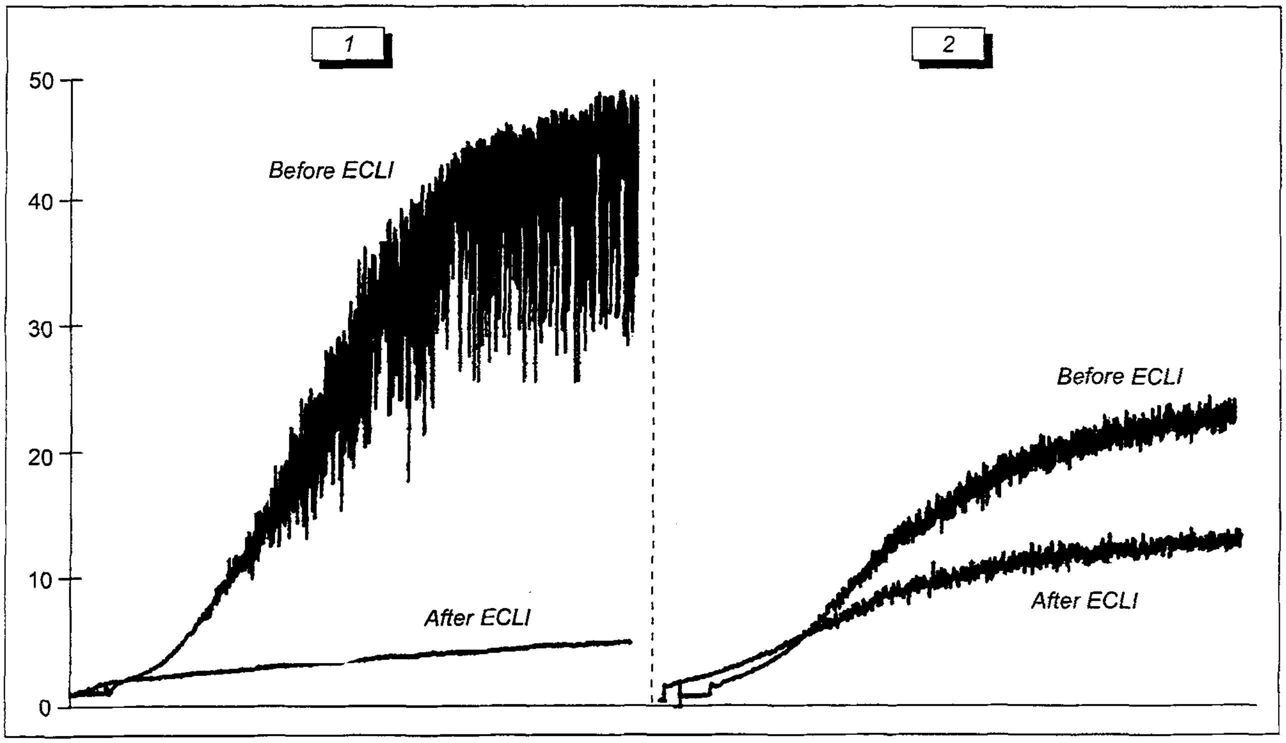

Fig. 2. Effect of ECLI on ristomycin-induced (*1*) and epinephrine-induced (*2*) platelet aggregation.

Thus, our findings indicate that intravascular and extracorporeal irradiation of the blood with HNL changes its rheological properties. This results from dilution of the blood, as is evidenced by the lowered hematocrit, plasma viscosity, and hemoglobin concentration. *In vitro* studies showed that direct irradiation with HNL does not reduce blood viscosity. Just why hemodilution occurs after the appearance of irradiated blood in the body is unclear. It may be induced by the deposition of erythrocytes, extravasation of plasma proteins due to increased permeability of the vascular wall, and inflow of isotonic protein-poor interstitial fluid. The duration and stability of the rheological shifts have yet to be studied.

A decrease in blood viscosity, irrespective of the mechanism of its development, induces an increase in the volume of the greater circulation according to the Farrheus-Lindquist law. This may best explain the positive results of treatment of chronic arterial insufficiency by irradiation of the blood with helium-neon laser.

REFERENCES

1. V. S. Zemskov, N. F. Gamaleya, Z. M. Rudnykh, *et al., Klin. Khir.,* № 12, 17-18 (1984).
2. S. M. Zubkova and I. B. Laprun, *Biol. Nauki,* № 4, 24-31 (1981).
3. T. Karu, *Dokl. Akad. Nauk SSSR,* **291**, № 5, 1245-1249 (1986).
4. M. F. Popova, T. A. Telegina, Sh. T. Il'yasova, and I. D. Bekhoev, *Ibid.,* **306**, № 2, 482-485 (1989).