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The Influence of Laser Blood Photomodification on Dynamic Characteristics of Surgical Stress

I. E. Golub, A. N. Malov, A. V. Neupokoeva, L. V. Sorokina, and Yu. N. Vygovsky

Institute for Laser Physics, Siberian Branch of RAS, 4038, Irkutsk-33, 664033 Russia
Irkutsk State Medical University, ul. Krasnogo Vosstaniya 1, Irkutsk, 664003 Russia

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Abstract—Investigation of laser photomodification of blood has shown the possibility to reduce the number of medicaments required for a certain level of patient's anesthesia. The blood laser photomodification alleviates the postoperative stress reactions, what manifests as a significant decay of amplitudes of 11 biochemical blood parameters during the entire postoperative period.

1. INTRODUCTION

The therapeutic effect of laser radiation is determined by physical processes occurring both in the organism as a whole and at lower levels such as the organ, cell, cell fragment, biomolecules, etc. The intravenous laser exposure of blood (ILEB) holds a special position among the variety of laser biostimulation methods due to the fact that blood is a biological component, which determines the functioning of the whole of the organism. Blood is the liquid that provides the exchange of all the nutrients and gases. The laser influence upon blood is apparently one of the most important aspects among the whole variety of laser-biostimulation effects. Thus, using data on the microcapillary blood flow [1], one can estimate the blood volume, undergoing laser action during 10-min irradiation of 1-cm^2 area of the finger skin, at 100 ml (whereas the total blood volume is 3–5 l). Therefore, the ILEB is evidently the most effective procedure with regard to therapeutic after-effects.

Though the effect of laser biostimulation of the circulatory system by means of the ILEB is now determined and has found the widespread practical use, the principle of its action remains unclear. On the one hand, it is considered that the laser irradiation changes the conformational property of hemoglobin molecules, thus resulting in the increase of the efficiency of oxygen metabolism. However, on the other hand, it stimulates the intensity of microcapillary circulation, what cannot be explained merely by the change of conditions of macromolecules, inasmuch as in microcapillaries the cooperative interaction of erythrocytes and vessel walls is significant (as is known, in nondeformable state erythrocyte sizes are larger than the microcapillary diameter) [1].

Furthermore, the surgical stress unavoidable in operative interventions is the permanently emerging factor in the medical practice, and during the postoperative period, it can cause damaging and transform into the pathogenesis factor. Although recently, the assortment of pharmaceuticals and pharmacological methods of general anesthesia, which allow the restriction of the surgical stress development, has significantly broadened, the problem as itself is still far from the ultimate solution. The main method allowing the limitation of the alteration effect of surgical stress at periods before the operation, during the operation and narcosis, as well as at the postoperative period is the directional activation of stress-limiting systems of the organism. Pharmacological measures are usually aimed at biochemical activation of one or several vital-activity regulation systems; however, at the same time the undesirable, side actions on other systems and functions often occur. Therefore, the problem of the combined application of methods of pharmacological narcosis and the ILEB to lower surgical stress in operative intervention [2] is topical.

In this work, we discuss the results of investigations of the ILEB application in the operative intervention combined with the pharmacological anesthesia.

2. SURGICAL STRESS

The surgical stress, unavoidable in operative interventions, can have a damaging effect during the postoperative period and transform into the pathogenesis factor. The main method allowing the limitation of the alteration effect of surgical stress before the operation, during the operation and narcosis, and at the postoperative period is the directional activation of stress-limiting systems of the organism [2]. Pharmacological measures are usually aimed at biochemical activation of one or several vital-activity regulation systems, however, at the same time, the undesirable side action on other systems and functions often appear.

The critically important fact is that patients of an elderly and senile age, mostly often undergoing operative interventions, have the significantly suppressed resistance and compensatory-adaptive potential of organism. They more often suffer from different concomitant diseases (atherosclerosis, ischemia, pancreatic diabetes, etc.), which burden both the main disease course, and the tolerance to surgical stress unavoidable in operative interventions. These circumstances to a significant degree influence the result of surgical treatment as well.

The response to stress, revealed by G. Selier and designated as the general adaptation syndrome, is the necessary link in the adaptation of the organism to dominant environment factors. Though a wide range of pharmaceuticals and pharmacological methods, allowing somewhat of the restriction of the surgical stress development, is now available, yet no assurance of a total lack of stress alteration effects and homeostasis derangements during and after the operative intervention exists.

As is known, the activity of stress-limiting systems, restricting the excessive effects of catecholamines, glucocorticoids and other agents capable of preventing damaging stress effect, rises under stress concurrently with the activation of stress-realizing systems. It is ascertained that two general methods—the adaptation of organism to environment factors and the introduction of mediators and metabolites of stress-limiting systems or their chemical analogs—can increase the power of these systems or modify their activity.

Clinical investigations [2] revealed that patients of an elderly and senile age undergoing hepatobiliary-system operations suffer from the most evident surgical stress. The dynamics of development of this stress has three main periods: preoperative, peroperative, and postoperative. The nowadays methods of the anesthetic protection do not completely limit the development of surgical stress, what manifests in a multiple increase of the blood corticosteroid content during operative interventions. General mechanisms, determining alteration effects of surgical stress through all stages of its development, imply the increase of concentration of products of glucose, aminotranspherase, histidase, etc., and the disturbance of both hepatic blood flow and the immune response. The revealed mechanisms of the surgical stress formation make it possible to optimize the algorithm of the anesthetic protection including the directional increase of the activity and power of stress-limiting systems of the organism in operative interventions by using the complex of activators of stress-limiting systems and the ILEB in schemes of the preoperative preparation, narcosis and postoperative treatment [2].

As is known, surgical stress paves the way for functional disorders, which proceed in the postoperative period as well. Apparently, the nociceptive impulses incoming from the location of tissue damages in the central nervous system (CNS), the emotional tension, immobility, and painful medical procedures are determining factors in the development of these disorders, thus resulting in the activation of stress-realizing systems and the development of alteration effects of the stress.

The development of surgical stress determines the pathogenetic response of the organism to different damaging effects. The surgical stress is the state of polyfunctional changes arising in patient's organism under the influence of aggressive factors, main of which are the neurosis, therapeutic and diagnostic manipulations, the wait for operation, preoperative fear, vegetative depression, pain, pathological non-algesic reflexes, posture effect of circulation, respiration, hemorrhage, and injuries of vital organs [3].

Under the pain stress, the shifts of interactions between the pacemaker structures of the algesic motivation and the projective cortical area take place in the CNS, and only after that, the shifts between subcortical structures.

During the surgical stress, the synergism between actions of adrenocorticotropic hormones and the adrenal medullary substance is observed; metabolic, energetic, and functional shifts, directed to the intensification of brain and heart blood supply, take place.

The stress stimulation of the sympathicoadrenal system results in the increase of brain and heart blood supply, owing to the enhancement of the amplitude and frequency of heartbeats as well as to the spasm of arterioles of all organs and tissues under the action of catecholamines [4].

The spasm of arterioles caused by catecholamines leads to the rise of the vascular resistance, disturbance of microcirculation, and afterwards to the disorder of blood flow properties, accompanied by the hypovolemia, ischemia of different organs and tissues, changes of water-electrolytic and acid-base states with the formation of biologically aggressive metabolites. It also breaks the reaction of bio-oxidation. These circumstances justify the expediency of the ILEB application.

The inflammatory component of surgical stress is now a prime consideration. As is supposed, this very factor provides the invariance of the stress state over a long period. Repeatedly proven interdependences of nervous, endocrine and immune systems of organism imply that under the homeostasis disturbance, caused by stress, these systems naturally engage into the action [5]. Under stress, adaptive resources of the organism become either sufficient for the adequate response or exhausted. This thesis can be equally well referred to the immune system of the human organism.

The interdependency of the nervous, immune, and endocrine systems of the organism is caused not only by the commonality of a number of receptors and determinants of cells of these systems. As is known, the secondary immune response is the adaptation to the antigen. The organism responds to the repeated introduction of antigen by the advanced immunoglobulin synthesis. It is ascertained that the ILEB has the stabilizing influence on the immune system [6, 7].

The prevention of surgical stress can be appropriate in that very case if the emotional arousal and disturbed functions of the organism, alleviating the narcosis realization, are sufficiently corrected at the preoperative period. During the operation, the anesthesia should limit the stress reaction by decreasing the nociceptive afferent pulsation [8]. At the postoperative period, the care should include the correction of functional disorders noneliminated during the operation, the reduction of the pain response, the emotional arousal, and the control of the organism function under emergent conditions [9].

3. THE INTRAVENOUS LASER EXPOSURE OF BLOOD AS THE ANTISTRESS-ACTING FACTOR

When the electromagnetic field of laser radiation interacts with intrinsic electromagnetic fields of a cell, the cell field changes and its free charge is being redistributed. In this connection, the structural changes of biologic liquids and membranes may take place [10, 11].

A number of biophysical and clinical investigations shows that the low-intensity laser radiation activates during blood exposure the important metabolic enzymes and the protein biosynthesis [3]. It improves the oxygen transport function of erythrocytes, blood flow properties [13, 14], the tissue regeneration [15], and microcirculation [1, 7], increases the activity of the immune system [7, 15], and activates the reparative processes [6], the challicrein–quinine system [16], antioxidant enzymes [17]. Under the low-intensity laser exposure, new capillaries can be formed, thus improving the oxygen delivery to tissues and optimizing the tissue metabolism [6, 7]. It is determined that the laser exposure normalizes the biochemical blood rates [18].

According to the results of [7], the elimination of the emotional preoperative stress is obviously concerned with the laser action on mechanisms of secretion and regulation of neuromediators and hormones of cortical adrenal substance. As is also determined, the low-intensity laser irradiation of blood has sedative and antistress effects [17].

Some authors consider that the laser radiation obviates the CNS imbalance disturbing the sanogenetic brain function. Depending on the initial state, the photobioactivation of tissues causes either the intensification or the suppression of their metabolism and functions, thus resulting in the decay of pathologic processes, normalization of organism functions, and the recovery of regulating functions of brain [6, 7]. There are some data indicating the enhancement of the oxygen metabolism under the low-energy laser irradiation, which also leads to the normalization of redox processes [12]. The low-intensity laser irradiation causes the photodynamical effect implying the change of the structure and function of cell membranes, the cellular apparatus activation, and the rise of the activity of DNA–RNA-protein systems. These processes determine the activation of cell functions and the stimulation of regeneration and metabolism.

The data given above testify that the laser radiation has the many-sided therapeutic effect, and the ILEB application in the operative intervention can be efficient.

4. CLINICAL INVESTIGATION TECHNIQUE AND EXPERIMENTAL RESULTS

The experimental investigations included the comparison of surgical-stress manifestations among three groups of patients. We selected 67 chronic cholecystitis patients including 14 men and 53 women and divided them into three groups. First-group patients (21 patients) underwent the conventional preoperative preparation (CP). For the second group (25 patients) the conventional preparation was combined with the ILEB. The laser power at the fiber output was 1.5–2.0 mW and the time of exposure was 40–60-min. The third group (21 patients) underwent the complex activation of stress-limiting systems (CASLM) including the CP, the introduction of gamma-oxybutyric acid, dalargin, alpha tocopherol, and the ILEB.

To induce general anesthesia, several variants of narcosis were used, namely, the standard neuroleptanalgesia (NLA), the NLA combined with the ILEB, and the NLA combined with the use of metabolites, which are the chemical analogs of stress-limiting systems, and the ILEB.

When applying the standard NLA, the total dose of fentanyl was 7.2 ± 0.1 μg/kg/h, and droperidol, 15.0 ± 2.5 μg/kg/h. For the NLA combined with the ILEB, the total fentanyl dose was 5.0 ± 0.3 μg/kg/h, and the total droperidol dose was 6.8 ± 2.1 μg/kg/h. The laser power at the fiber output was 1.5–2.0 mW and the exposure time was 45–60 min. For the NLA combined with the introduction of mediators and metabolites of stress-limiting systems, and the ILEB, the total dose of fentanyl was 0.7–0.8 μg/kg/h, droperidol, 2.8 μg/kg/h, alpha tocopherol, 4–5 mg/kg. For two latter cases, the laser radiation power at the fiber output was 1.5–2.0 mW and the time of exposure was 45–60-min.

After the operation, the complex intensive care, aimed at the correction of the emotional arousal, pain syndrome, inflammatory reactions, water–electrolytic and acid–base states as well as at the maintenance of functions of cardiovascular and respiratory systems, was carried out. The care included the conventional therapy, the conventional therapy combined with ILEB, and the conventional therapy with complex activation of stress-limiting systems of the organism by means of introduction of sodium oxybutyrate, dalargin, and alpha tocopherol and the ILEB.

According to the formulated purposes, the studied rates were examined at different stages before, during and after the operation:

(1) at the admission of a patient to hospital,

(2) after different variants of preoperative preparation,

(3) 20 min before the operation,

(4) at the traumatic stage of the operation,

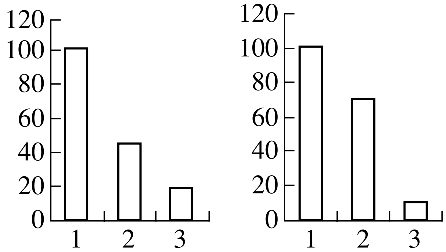

Fig. 1. Dose of anesthetic agent for different methods of analgesia: (1) the standard NLA, (2) the NLA + ILEB, (3) the NLA + ILEB + CASLM. The left diagram shows properidol dose; right diagram, fentanyl. The anesthetic dose for the standard NLA is assumed to be 100%.

(5) after the operation and the narcosis termination,

(6) at first day after the operation, under the postoperative therapy of different kinds,

(7) at third day after the operation, under the postoperative therapy of different kinds,

(8) at the fifth to seventh day after the operation, under the postoperative therapy of different kinds,

(9) at the 10–12th day after the operation, under the postoperative therapy of different kinds.

The tested blood was centrifugalized. The blood plasma was instantly congealed in polyethylene tubes and was stored in the frozen state until the examination. The probes for cortisol and alpha tocopherol were stored separately, what allowed us to avoid the repeated unfreezing.

To estimate the antistress action of different variants of general therapy before, during, and after the operation, we used the clinical signs and biochemical factors reflecting different sides of the metabolism, namely:

(1) cortisol,

(2) diene conjugates (DC),

(3) malonic dialdehyde (MDA),

(4) antioxygenic activity (AOA),

(5) alpha tocopherol,

(6) lactic acid (LA),

(7) pyruvic acid (PVA),

(8) glucose,

(9) alanine aminotransferase (ALT),

(10) aspartate aminotransferase (AST),

(11) histidase.

The data shown in Fig. 1 indicate the possibility to lower the dose of anesthetic by applying the ILEB.

According to the obtained data, the diagrams (Figs. 2–4) demonstrating the dynamics of the above-mentioned blood parameters during preoperative, operative and postoperative periods are plotted. The above-mentioned blood parameters denoted by corresponding numbers are plotted on the *X*-axis, stages of the therapy, on the *Y*-axis, the content or activity of each parameter, expressed in percent of normal value, is plotted on the

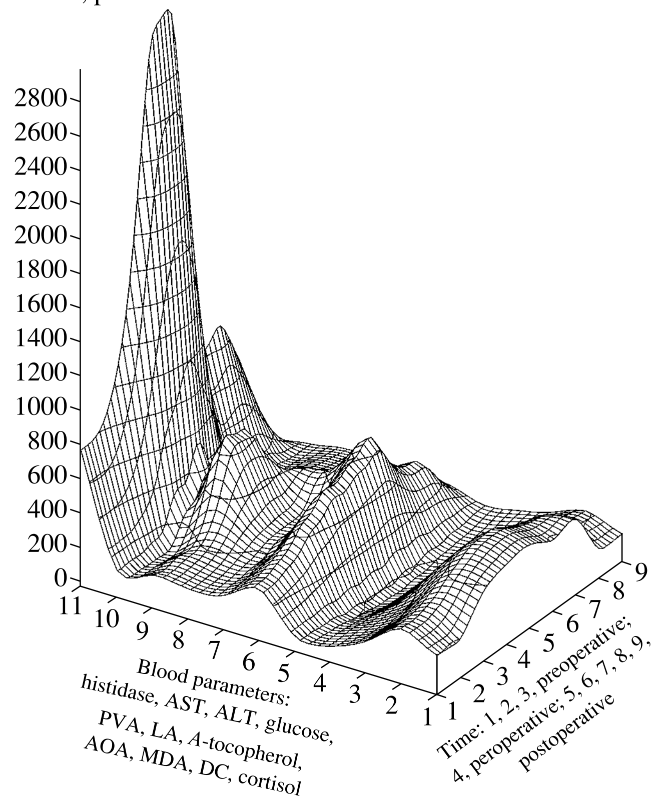

Fig. 2. The dynamics of blood parameters at different stages of treatment under the conventional anesthesia scheme.

Z-axis. The control group, which characteristics were assumed as the norma, includes 35 virtually healthy persons without any clinical and laboratory signs of pathology in the past and at the examination moment. The first diagram represents the dynamics of blood parameters in case of the conventional preoperative preparation, standard NLA, and the conventional postoperative therapy. The second diagram shows the change of blood parameters when applying the ILEB at all of three stages. The third diagram shows the dynamics of those parameters when applying both the ILEB, and mediators and metabolites of stress-limiting systems.

Patients of all groups underwent the single-type, standard premedication according to the following scheme: for the night before the operation they were prescribed the 5–10-mg dose of one of tranquilizers, dimedrol or suprastin, and 20-mg pipolphen; an hour prior to the operation doses of antihistamines were repeated; 40 min before the operation the 0.5–1.0-mg atropine sulfate and 20-mg promedol were subcutaneously introduced. The 2.5% sodium hyopental or hexenal solution was used as the initial narcosis among all of the groups of patients. The intubation of trachea was performed against the background of a maximum effect of 100–160-mg succinocholine.

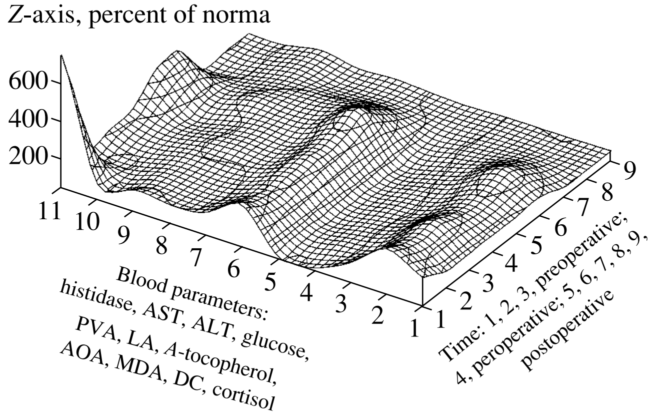

Fig. 3. The dynamics of blood parameters at different stages of treatment under the anesthesia with the ILEB.

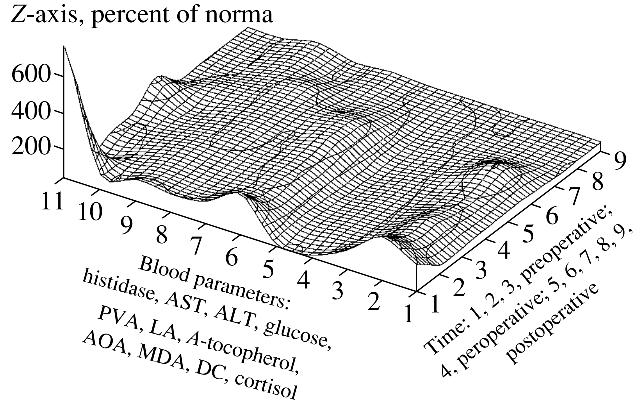

Fig. 4. The dynamics of blood parameters at different stages of treatment under the anesthesia with the ILEB and the CASLM.

All operations were accomplished by the mechanical ventilation of lungs, which was realized by means of volume respirators of RO-6 series over the half-closed circuit or manually by the nitrous-oxide–oxygen mixture with the 2:1 ratio in a moderate hyperventilation regime. The regime of ventilation and hemodynamics was controlled by the pulsoxymetry and cardiomonitoring using the "Optim-420" device and "Elon-001" rhythmocardiomonitor. The noted stages of investigations provided the practically complete characterization of the dynamics of the formation and development of surgical stress.

The comparison of results of biochemical monitoring of patient conditions under the ILEB with the parameters of patients undergoing the conventional anesthesia testifies the positive influence of the laser blood photomodification. The degree of surgical stress (the amplitude of fluctuation of all of 11 blood parameters) recedes, and the dose of pharmaceuticals necessary to achieve the required anesthetic profundity decreases. Dynamical characteristics of surgical stress under the ILEB given in Figs. 3, 4 entail the following conclusions:

• the laser blood photomodification, in contrast to the drug intervention, positively influences the entire family of blood parameters;

• the dynamics of postoperative fluctuations of blood parameters is significantly improved, what indicates the faster return of patient to the homeostasis;

• the ILEB is compatible with pharmacological and other procedures of the general anesthesia and does not cause the suppression of any vital systems.

Generalizing given data, we can note that in the case of the conventional postoperative therapy the endogenous alpha tocopherol is not completely mobilized at the postoperative period, and the stress activation of POL processes is not limited, thus resulting in the suppression of the antioxidant activity and the deficiency of alpha tocopherol. The use of metabolites and analogs of stress-limiting systems, and their complex activation can substantially prevent and limit the stress activation of POL, raise the antioxidant activity and normalize the alpha tocopherol content.

From the physical point of view, the highly monochromatic laser radiation falling into the nonlinear optical medium (blood) generates a broad spectrum of Raman frequencies (coinciding with frequencies of different elementary biochemical subsystems). In this case, the sharpest resonance occurs at the frequency common for all of the oscillatory subsystems. Apparently, one of the brain and CNS rates is such a common frequency. The availability of the intense and structurally rich Raman spectrum in every of biochemical subsystems facilitates the structural reconstruction of all of oscillatory systems by tuning their frequencies to the master rate of the organism as a whole. The nonspecific action of laser radiation upon stress-forming systems takes them out of the "stress-homeostasis" state (which is characterized by significant fluctuations of amplitudes of blood parameters), thus facilitating the regulating function of stress-limiting systems. The fact that the coherent radiation acts upon all of subsystems (and blood parameters) at once is readily apparent from the stated above. The electromagnetic field influences all reactions proceeding in the organism just on the level of the interaction of ions and/or macromolecule fragments, which is the fundamental and inevitable part in the biochemical synthesis of enzymes, hormones, proteins, etc, induced by any subsystem.

Thus, the antistress effect of the combined therapy is caused by the fact that the employed stress-limiting substances and the ILEB increase the activity of the antioxidant stress-limiting system both directly and by means of the mediated action through other stress-limiting systems.

5. CONCLUSIONS

The results represented above can be summarized in the following way.

—The conventional preoperative preparation and postoperative therapy as well as the conventional anesthesia employing neuroleptanalgetsia agents are not efficient enough to prevent the development and the alteration effect of surgical stress.

—The He–Ne laser irradiation of blood facilitates the decrease of the cortisol concentration level through all stages of the surgical stress development, inhibits the hyperlipoperoxidation, stimulates the antioxygenic activity, increases the alpha tocopherol content, abates enzymology and the level of keto acids, and normalizes the adrenal blood flow and immunity rate.

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