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ЛАЗЕРНОЕ ОСВЕЧИВАНИЕ КРОВИ: ОСНОВНЫЕ ТЕРАПЕВТИЧЕСКИЕ МЕТОДЫ (систематический обзор литературы)

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Аннотация. Анализ публикаций, посвященных исследованию механизмов терапевтического эффекта одного из самых известных методов низкоуровневой лазерной терапии - лазерного освечивания крови, а также анализ длительного опыта применения данного метода позволяют авторам с уверенностью говорить о перспективах этого направления. Оба метода: внутривенное лазерное освечивание крови и неинвазивное лазерное освечивание крови развиваются независимо, так как каждый метод имеет свои преимущества и недостатки.

Замена ультрафиолетового освечивания крови с помощью ультрафиолетовых ламп на *лазерное ультрафиолетовое освечивание крови* (ЛУОК) значительно упростила применение данного метода и повысила его эффективность. Наиболее эффективными для *внутривенного лазерного освечивания крови* (ВЛОК) являются сочетанные методы: ВЛОК-635 + ЛУОК® и ВЛОК-525 + ЛУОК®. Наиболее эффективным методом для неинвазивного лазерного освечивания крови является низкоинтенсивное импульсное лазерное излучение, в котором длина волны 635 нм и мощность до 40 Вт.

Ключевые слова: низкоуровневая лазерная терапия, внутривенное лазерное освечивание крови, неинвазивное лазерное освечивание крови, лазерное ультрафиолетовое освечивание крови.

LASER BLOOD ILLUMINATION: THE MAIN THERAPEUTIC TECHNIQUES (systemized literature review)

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Abstract. The analysis of the publications devoted to the research of the mechanisms of the therapeutic effect of one of the most known low level laser therapy techniques –laser blood illumination, as well as the analysis of its long application experience allow us to speak with confidence about the prospects of this trend. Moreover, both methods: intravenous laser blood illumination (ILBI) and non-invasive laser blood illumination (NLBI) are developing independently, since each method has its own advantages and disadvantages.

The replacement of UV blood illumination with UV lamps by laser ultraviolet blood illumination (LUVBI®) has significantly simplified the technique and increased its efficiency. The most efficient options for ILBI are combined techniques: ILBI-635 + LUVBI® and ILBI-525 + LUVBI®. The most efficient technique for NLBI is the use of low-intensity pulsed laser light with a wavelength of 635 nm and power of up to 40 W.

Key words: low level laser therapy, intravenous laser blood illumination (ILBI), non-invasive laser blood illumination (NLBI), laser ultraviolet blood illumination (LUVBI®)

Low level laser therapy is one of the methods of physiotherapy which gained its popularity in the USSR first and then in Russia. In the English-speaking publications devoted to the subject, it is stated that the Hungarian researchers were the first to suggest the method[1]. However, dozens of studies on the therapeutic application of *low-intensity laser irradiation* (LILI) were carried out in a number of former Soviet Republics at that time and hundreds of articles and even monographs were published, but as they were all written in Russian language, they were ignored by the global professional community. It is undeniable that at the moment Russia is the main leader in this field, as it is Russian specialists who create the most efficient techniques of laser therapeutic effect.

The absolute safety of low level laser therapy and its efficiency were proven long ago [2, 3], the mechanisms of the therapeutic (biological) effect of *low-intensity laser irradiation* (LILI) have been studied thoroughly [4,5], which makes it possible to develop thetrendmore actively in generaltogether with its differenttechniquesin particular.

One of the most famous low level laser therapy techniques is laser blood illumination [6-8] which is implemented intwo options: invasive (intravenous) and non-invasive (transdermal). *Intravenous laser blood illumination* (ILBI) was first applied in clinical practice (cardiology and cardiac surgery) by E.N. Meshalkin and V.S. Sergievsky (1981, 1989) [9, 10] with the help of HeNelasers with a wavelength of 633 nm and powerof 1-2 mW, but nowadays LILI is applied with different wavelengths (from UV toIR spectrum) and powerof 1-2 to 25 mW [11, 12]. Pulsed *laser diodes* (LD) of red spectrum (wavelength of 635 nm, pulse duration of 100-150 ns, pulse power of 5 W for a single LD and up to 40 W for a matrix of 8 LDs) are more often used for *non-invasive laser blood illumination* (NLBI), particularly matrix LD [13, 14].

The number of areas of application of laser blood illumination for therapeutic effects is increasing:

– obstetrics and gynecology [15];
– dermatology and cosmetology [16];
– neurology [17, 18];
– otorhinolaryngology [19];
– pediatrics [20];
– psychiatry [21];
– dentistry [22];
– urology [23] etc.

The techniques of laser blood illumination are constantantly being improved.The interest in these Russian medical technologies has increased all over the world recently, but the article deals with their main options only and the number of their modifications can be fairly great. But let us take two things into account. First of all, extracorporeal blood illumination was applied only with the use of non-coherent light sources (lamp), laser light energy delivery is implemented much more easily – intravenous (through the light guide) and non-invasive (transdermal). Secondly, NLBI is always about the impact over large blood vessels. Irradiation of peripheral vessels in any localization like “laser watch” on the wrist[24] or endonasal [25] (Chinese versions) is a merediscredit of the method [6].

This research is a “systemized review” as it is impossible to quote even the main publications on the subject because of their great number, what is more important is to follow the trends of the method development. Those, who would like to have the list of references and some publications on open access, can contact the authors. There are not so many articles in English, not more than 30, but there is an impressive amount of articles in Russian language, not less than 5000 (more than 300 patents have been granted)[26], that is why only some review is carried out and different research data is systemized in basic therapeutic schemes and recommendations.

To understand the improvement strategy of low level laser therapy techniques with the aim to increase their efficiency it is necessary to know the mechanisms of LILI biomodulationaction, which can be presented in the following sequence: as a result of irradiation a temperature gradient occurs inside a cell and there is a momentary increase of the concentration of calcium ions (Ca^{2+}) released from intracellular stores, with the development of the cascade of the organism’s responses to the external influence: the work of immune system and vascular systemnormalizes, metabolic and proliferative processes are activated, analgesic effect is provided, etc. (Fig. 1) [4, 5, 27, 28]. It is necessary to take into consideration the fact that all laser-induced bioeffects are Ca^{2+}-dependent, that explains non-specificity and versatility of the living organism’s responses. The nonlinear nature of the relations “energy density of LILI – effect” and “exposure (irradiation time) – effect” is due to the peculiarities of work of intracellular calcium stores, and the lack of action spectrum (specific LILI wavelength dependence) is due to the thermodynamic nature of theirinclusion (launch of the process of calcium ions release).

Let us pay attention to the fact, that all the aforementioned is only relevant to “*laser*-“ biomodulation, not “photo-“ or “light-“ biomodulation, that is true only for monochromatic *laser* light. In *laser* therapy (low level *laser* therapy) only *lasers* or *laser* diodes (LD) are used. Unfortunately, *laser* diodes are quite often substituted with inefficient, almost useless but cheap *light-emitting* diodes (LED), which is totally unacceptable.

Correct understanding of the mechanisms of LILI biomodulation action makes it possible to work out recommendations for efficient low level laser therapy application and creates the basis fordevelopment of new techniques.

In modern laser therapeutic equipment, laser diodes which allow the useof remote laser emitting headscustomized according to the delivery methods are most often used. Devices of “LASMIK” (Fig. 2) series allow intravenous and non-invasive laser blood illumination, as well as othertechniques of laser treatment. Maximum therapy efficiency is also due to the optimization of the laser head design, for example, a special fixing system of disposable light guides and heads on the arm is used for ILBI (Fig. 2, bottom left), matrix emitting heads are used for NLBI (Fig. 2, bottom right, Fig. 3).

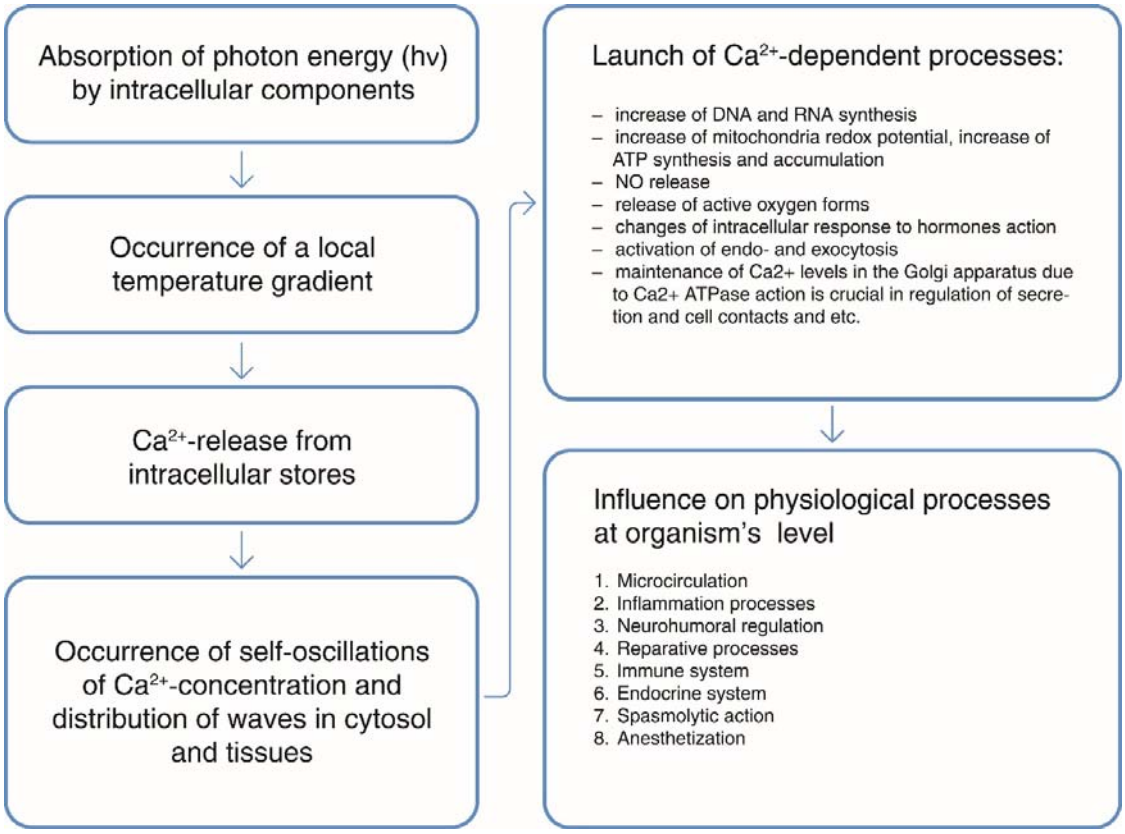

Fig.1. The sequence of the development of biological effects due to laser irradiation

Fig. 2. Laser therapy device "LASMIK" can be used for ILBI as well as NLBI

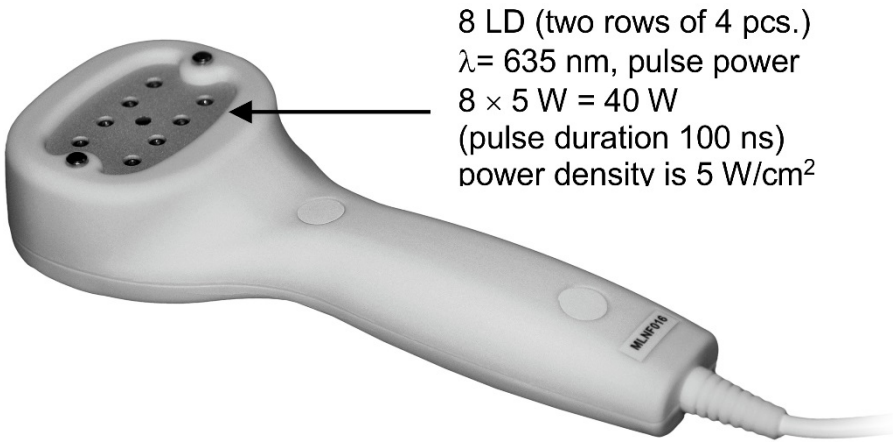

Fig. 3. Matrix laser emitting head ML-635-40 for efficient NLBI

Protocol Requirements of Low Level Laser Therapy Procedures in Russia, Low Level Laser Therapy Techniques

Protocol requirements are strictly obligatory as the necessity to set *all* the parameters of the method listed below has been clearly proven. It will be impossible to get a predictable and appropriate response to the laser light impact and to achieve the desired therapeutic effect if only one of the parameters is implemented incorrectly.

Let us take into account the fact that in most cases minimum LILI energy is required for the successful implementation of low level laser therapy techniques. However, there are techniques which require power density limits, but there are not so many of them.

All low level laser therapy techniques must contain the following information [6-8].

1. Laser light wavelength is measured in *nanometers* [nm]. Here are the wavelengths which are the most common in laser therapy:
   - 365-405 nm – *ultraviolet* (UV) spectrum,
   - 440-445 nm – blue spectrum,
   - 520-525 nm – green spectrum,
   - 635 nm – red spectrum,
   - 780-785 nm – *infrared* (IR) spectrum,
   - 890-904 nm – *infrared* (IR) spectrum.

It is not allowed to irradiate the same area with laser and/or incoherent light sources with a different wavelength simultaneously because of inhibitory interaction.

2. Laser operation mode: continuous, modulated, pulse.
3. LILIradiationpower.

The average power of continuous lasers, operating in continuous or modulated modes is measured in *milliwatts* (mW), pulse (peak) power of pulsed lasers is measured in *watts* (W).

4. Modulation frequency or pulse for a pulsed mode is a quantity of fluctuations (pulses) per a unit of time (second). It is measured in *Hertz* [Hz, 1/s].

5. The duration of light pulse is a very important parameter for pulsed lasers, it is constant (most often 100-150 ns).Average power of *pulsed lasers* ($P_{av.}$) is directly proportional to *pulse power* (P_p), *pulse duration* (τ_p) and frequency (F_p): $P_{av.} = P_p \times \tau_p \times F_p$.

6. Irradiation area. It is measured in square *centimeters* [cm^2].

The required area is almost always defined by the technique itself without unnecessary measurements, for example, for a contact-mirror technique the area is supposed to be 1 cm^2. Laser diodes in matrix emitters must be arranged so that their impact area is multiplied by power density. For example, 8 (most often) pulsed laser diodes, each with the power of 10 W, are placed on the area of 8 cm^2, and upon the contact with the skin the power density will be 10 W/ cm^2 respectively. For laser acupuncture or *intravenous laser blood illumination* (ILBI) the area is not indicated, because the impactarea is too small and dispersion and absorption of the laser light energy in the volume of biological tissues are of primary importance.

7. *Power density* (PD). It is measured in watts and milliwatts per a square centimeter [W/cm^2 or mW/cm^2].

8. Exposure (exposure time) on one area (zone) and total duration of the procedure is measured in *seconds* [s] or *minutes* [min].This is an extremely important parameter which can hardly ever be changed. Total

duration of the low level laser therapy procedure (consistent effect on all the areas) should not exceed 20 minutes, for one area – 5 minutes (except for intravenous laser blood illumination).

9. Exposure localization (technique).

10. The number of procedures per course of treatment and their frequency.

Calculations of energy measured in joules [J or W×s] and energy density [J/cm^2 or W×s /cm^2] are not carried outas there is no need in this information for an efficient laser therapy.

It is expedient to include one of the general effect methods into a low level laser therapy scheme (laserpuncture and/or ILBI) and direct impact on the affected area (local, transdermal or abdominal technique, and a combined method – laser phoresis).

Local LILI is applied directly on the affected area located close to the surface of a body or contact through a mirror head, or remote at a small distance from the surface (1-2 cm) in a stable manner.

The following types of LILI are most often used for local laser irradiation:

– continuous LILI of red spectrum (635 nm), PD – 10-15 mW/cm^2,

– pulsed LILI of red spectrum (635 nm), PD – 4-5 W/cm^2, pulse duration 100-150 ns, frequency 80-10000 Hz,

– pulsed IR LILI (890-904 nm), PD – 8-10 W/cm^2, pulse duration 100-150 ns, frequency 80-10000 Hz.

For pulsed lasers, frequency varies according to the desired effect: regeneration and anti-inflammatory effect – 80-150 Hz, anesthesia – 3000-10000 Hz. There are up to 2-3 local zones for one area, exposure to each is 2-5 min. A more than a five-minute exposure to one zone is not allowed.

Intravenous Laser Blood Illumination

A continuous mode LILI is used, the exposure is implemented intravenously through special disposable sterile light guides with a punctureneedle (Fig. 4), most often in cubital vein (Fig. 5 and Fig. 6, zone 1) [12].

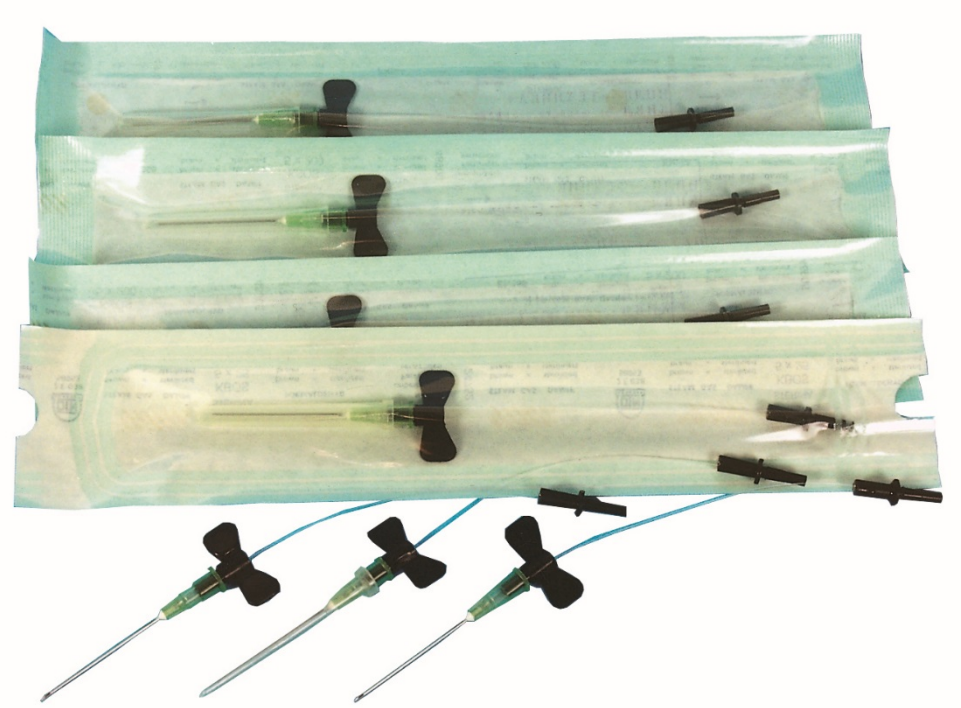

Fig. 4. Disposable sterile light guides for ILBI

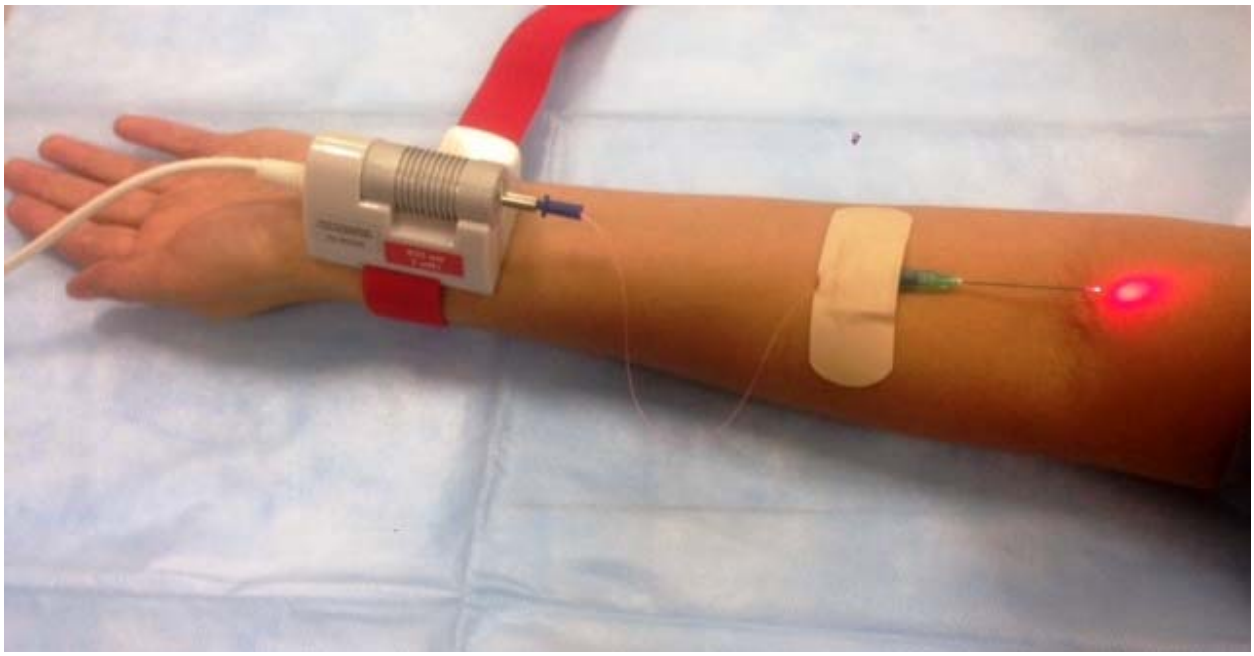

Fig. 5. ILBI procedure

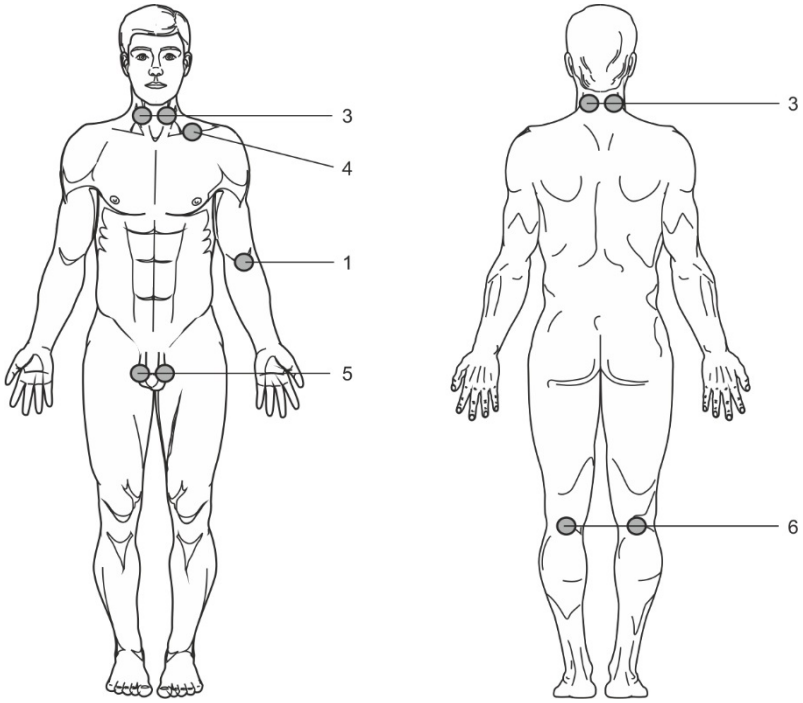

Fig. 6. Main areas of laser blood illumination

Differentiated techniques with the use of laser light of different spectrum (Table 1) are used at the present time for ILBI implementation:

– *ILBI-635* (wavelength of 635 nm, red spectrum, power of 1.5-2 mW, exposure 10-20 min) has a universal effect, a positive effect on the immune system as well as on the trophic provision of tissues.

– *ILBI-525* (wavelength of 525 nm, green spectrum, power of 1.5-2 mW, exposure 7-8 min) is recommended for maximum enhancement of the trophic provision of tissues.

– *ILBI-365 and ILBI-405 – laser ultraviolet blood illumination* (LUVBI®,wavelength of 365-405 nm, power of 1,5-2 mW, exposure 3-5 min) is preferable for the correction of immune disorders as a result of a disease or injury.

Table 1

ILBI-635 («classical», basic), ILBI-525, ILBI-365, ILBI-405 (LUVBI®) Techniques

Parameter	Value	Note
Laser light wavelength, nm (spectrum)	635 (red)	ILBI-635
	525 (green)	ILBI-525
	ILBI-365 (ultraviolet)	LUVBI®
	ILBI-405 (violet)	
Laser operation mode	Continuous	–
Irradiation power*, mW	1,5–2	At the output of a disposable light guide
Exposure, min	10–20	ILBI-635
	7-8	ILBI-525
	3-5	LUVBI®
	3-5	
Localization	Median cubital vein (*v. mediana cubiti*)	Fig. 6, zone 1 (in the left or right arm)
Technique	Intravenously	Through a disposable sterile light guide
Number of procedures per course of treatment	10–12	–

There are many options of the techniques and the rules of parameter variation which must not be broken.

Power (1,5-2 mW) is not changed, but can be increased up to 20-25 mW in some cases with the use of special laser emitting heads or is changed from one procedure to another. But it is necessary to be extremely careful with this regulation and use it only on purpose and for some nosological forms only.

Exposure. "Standard" time for ILBI-635 procedure can be increased, sometimes to 25-30 minutes, but not more [10]! It is necessary to know the peculiarities of ILBI-635 application in the older age group (2 times decrease of the exposure) [29]. There is a rule in pediatrics "the younger the age the less the exposure" [20, 30], for ILBI-635 the exposure is decreased to 5-7 min, though we are sure, that for children it is almost always possible-to substitute the intravenous technique with the external irradiation of the supraclavicular area.

Now combined techniques ILBI-525 + LUVBI® (Table 2) and ILBI-635 + LUVBI® (Table 3) are gaining more and more popularity. We emphasize the fact that irradiation is implemented every other day, it is strictly PROHIBITED to implement ILBI with a different wavelength for the same patient on the same day, especially simultaneously.

Table 2

ILBI-525 + LUVBI®(basic) Technique

Parameter	Value	Note
Laser light wavelength, nm (spectrum)	365–405 (UV)	LUVBI®
	520-525 (green)	ILBI-525
Laser operation mode	Continuous	–
Irradiation power *, mW	1,5–2	At the output of a disposable light guide
Exposure, min	3–5	LUVBI®
	7–8	ILBI-525
Localization	Median cubital vein (*v. mediana cubiti*)	Fig. 6, zone 1 (in the left or right arm)
Technique	Intravenously	Through a disposable sterile light guide
Number of procedures per a course of treatment	10–12	Daily, alternating ILBI-525 and LUVBI® every other day

Table 3

ILBI-635 + LUVBI® Technique

Parameter	Value	Note
Laser light wavelength, nm (spectrum)	365–405 (UV)	LUVBI®
	635 (red)	ILBI-635
Laser operation mode	Continuous	–
Irradiation power*, mW	1,5–2	At the output of a disposable light guide
Exposure, min	3–5	LUVBI®
	10–20	ILBI-635
Localization	Median cubital vein (*v. mediana cubiti*)	Fig. 6, zone 1 (in the left or right arm)
Technique	Intravenously	Through a disposable sterile light guide
Number of procedures per a course of treatment	10–12	Daily, alternating ILBI-635 and LUVBI® every other day

Alterning the procedures allow optimization of the effect on the immune system on the days when LUVBI® is implemented as well as the trophic provision of tissues on the days when ILBI-635 or ILBI-525 are implemented (more efficient option).

Non-Invasive Laser Blood Illumination

It is implemented over*large* blood vessels (arteries and veins) close to the injury area. Pulsed lasers of red (635 nm) or infrared (890-904 nm) spectrum and matrix (8 laser diodes) emitters with irradiation areas of 10 cm^2 (Fig. 3), or as an option, with a single laser with a mirror head with irradiation area of 1 cm^2 are used for NLBI. The power density is identical in any case. [Moskvin S.V. et al., 2007] (Table 4):

Table 4

NLBITechnique

Parameter	Value	Note
Laser light wavelength, nm (spectrum)	635 (red)	NLBI-635
	904 (infrared)	NLBI-904
Laser operation mode	Pulsed	–
Lightpulseduration, ns	100–150	–
Irradiation power, W	30–40	Matrixemittinghead, NLBI-635
	60-80	Matrixemittinghead, NLBI-904
Power density, W/cm^2 (surface area of 10 cm^2)	3–4	NLBI-635
	6-8	NLBI-904
Frequency, Hz	80–150	–
Exposureon 1 zone, min	2–5	–
Numberofzones	2–4	Symmetrically
Localization	On the projection oflarge blood vessels close to the lesion area	See the text
Technique	Contact	Through a transparent nozzle
Number of procedures per a course of treatment	10–12	Daily

– NLBI-635, the most effective option, pulsed LILI of red spectrum (635 nm), PD – 4-5 W/ cm^2, pulse duration 100-150 ns, frequency 80 Hz,

– NLBI-904, pulsed IR LILI (890-904 nm), PD – 8-10 W/cm^2, pulse duration 100-150 ns, frequency 80 Hz.

The following irradiation localizations are used for NLBI (Fig. 6):

– the projection of the common carotid artery (carotid sinus area) symmetrically (zone 2),

– the projection of the vertebral artery symmetrically (zone 3),

– supraclavicular area on the left (zone 4),

– vascular bundles in the groin area symmetrically (zone 5);

– popliteal symmetrically (zone 6).

Pulse is fixed (80-150 Hz), the problem of the possibility andpermissibility of the frequency increase (the average power for pulsed lasers) has not been studied yet. It is recommended to irradiate symmetric zones with the exposure time of 2-5 min. on each zone. It is prohibited to irradiate one zone for more than 5 min.!

The main advantages and disadvantages of the two techniques of the blood illumination are briefly presented in Table 5.

Table 5

Intravenous and Non-invasive Techniques Comparison

Parameter	ILBI-635	NLBI-635
Low cost	No	Yes
The simplicity of realization	No	Yes
Thepotentialforinfection	Yes	No
Supplies	There are	No
Localization of the irradiation	Median cubital vein (*v. mediana cubiti*)	On the projection oflarge blood vessels (arteries or veins) close to the lesion area
Exposure, min	2-30	Not more than 5
Trauma	Yes	No
Additional requirements to the room, where the procedure is implemented	Yes	No
Efficiency	Less	More
Time of the procedure, min	7–30 (average 15)	2–5
Additionalpsychologicaleffect	There is	No

The analysis of the publications devoted to the research of the mechanisms of the therapeutic effect of one of the most known low level laser therapy techniques - laser blood illumination, as well as the analysis of its long application experience allows us to speak with confidence about the prospects of this trend. Moreover, both methods: intravenous laser blood illumination (ILBI) and non-invasive laser blood illumination (NLBI) are developing independently, since each method has its own advantages and disadvantages.

The replacement of UV blood illumination with UV lamps by laser ultraviolet blood illumination (LUVBI®) has significantly simplified the technique and increased its efficiency. The most efficient options for ILBI are combined techniques: ILBI-635 + LUVBI® and ILBI-525 + LUVBI®. The most efficient technique for NLBI is the use of low-intensity pulsed laser light with a wavelength of 635 nm and power of up to 40 W.

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