UDC 616.831-001-06-085.849.19(045)
DOI – https://doi.org/10.14300/mnnc.2019.14140
ISSN – 2073-8137

POSSIBILITIES OF LOW-INTENSITY LASER IRRADIATION OF BLOOD AND ASPECTS OF EVIDENCE OF ITS EFFECTIVENESS IN THE TREATMENT OF CONTUSION FOCI AND INTRACRANIAL HEMATOMAS OF SMALL VOLUME

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ВОЗМОЖНОСТИ НИЗКОИНТЕНСИВНОГО ЛАЗЕРНОГО ОБЛУЧЕНИЯ КРОВИ И АСПЕКТЫ ДОКАЗАТЕЛЬНОСТИ ЕГО ЭФФЕКТИВНОСТИ В ЛЕЧЕНИИ КОНТУЗИОННЫХ ОЧАГОВ И ВНУТРИЧЕРЕПНЫХ ГЕМАТОМ МАЛОГО ОБЪЁМА

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In review showed that in the foci of concussion and intracranial hematomas of small volume when using a course of low-intensity laser radiation, several positive therapeutic effects are observed due to microcirculatory, metabolic, and neuro-reflex mechanisms. These mechanisms are closely interrelated and in many ways, complement each other. Improvement of microcirculation is achieved by increasing the volume rate of arterial and venous blood flow, normalization of vascular tone, strengthening the functioning of natural and the formation of new anastomoses and collaterals, reducing blood clotting activity, improving its rheological properties. The mechanism for improving metabolic metabolism is associated with the ability of low-intensity laser radiation to activate biosynthetic and redox processes in brain cells. The literature review reveals the versatile properties of low-intensity laser radiation in the foci of concussion and intracranial hematomas of small volume.

Keywords: laser irradiation, blood, neuron-specific proteins, traumatic brain injury

Проведенные исследования и анализ литературы показали, что в очагах контузии и внутричерепных гематом малого объема при использовании курса низкоинтенсивного лазерного излучения отмечается ряд положительных терапевтических эффектов, обусловленных микроциркуляторными, метаболическими и нейро-рефлекторными механизмами. Эти механизмы тесно взаимосвязаны и во многом дополняют друг друга. Улучшение микроциркуляции достигается путем увеличения объемной скорости артериального и венозного кровотока, нормализацией сосудистого тонуса, усилением функционирования естественных и формированием новых анастомозов и коллатералей, а также снижением свертывающей активности крови и улучшением ее реологических свойств. Механизм улучшения метаболического обмена связан со способностью низкоинтенсивного лазерного излучения активизировать биосинтетические и окислительно-восстановительные процессы в клетках головного мозга. В обзоре литературы раскрываются разносторонние свойства низкоинтенсивного лазерного излучения в очагах контузии и внутричерепных гематом малого объема.

Ключевые слова: лазерное облучение, кровь, нейроспецифические белки, черепно-мозговая травма

For citation: Chekhonatsky A. A., Komleva N. E., Chekhonatsky V. A., Lymarev M. V., Veretelnikova Yu. Ya. POSSIBILITIES OF LOW-INTENSITY LASER IRRADIATION OF BLOOD AND ASPECTS OF EVIDENCE OF ITS EFFECTIVENESS IN THE TREATMENT OF CONTUSION FOCI AND INTRACRANIAL HEMATOMAS OF SMALL VOLUME. *Medical News of North Caucasus*. 2019;14(3):557-560. DOI – https://doi.org/10.14300/mnnc.2019.14140

Для цитирования: Чехонацкий А. А., Комлева Н. Е., Чехонацкий В. А., Лымарев М. В., Веретельникова Ю. Я. ВОЗМОЖНОСТИ НИЗКОИНТЕНСИВНОГО ЛАЗЕРНОГО ОБЛУЧЕНИЯ КРОВИ И АСПЕКТЫ ДОКАЗАТЕЛЬНОСТИ ЕГО ЭФФЕКТИВНОСТИ В ЛЕЧЕНИИ КОНТУЗИОННЫХ ОЧАГОВ И ВНУТРИЧЕРЕПНЫХ ГЕМАТОМ МАЛОГО ОБЪЁМА. *Медицинский вестник Северного Кавказа.* 2019;14(3):557-560. DOI – https://doi.org/10.14300/mnnc.2019.14140

GFAP – glial fibrillary acidic protein
LI – laser irradiation
NSE – neuronspecific enolase
TBI – traumatic brain injury
α2-MG – α2-macroglobulin

Traumatic brain injury (TBI) is the current issue in health service and any social system in general. The brain injury is one of the leading causes of death and disability, especially among adults of working age according to mortality statistics [1–5].

According to WHO, in many countries, the incidence rates for traumatic brain injury are increasing, being annually rising by 2 %. The most common subjects of papers with the highest annual citation rates of TBI are the treatment of brain concussion (63–90 %), bruises of the brain (5–13 %), and cerebral compression (1–3 %). Neurotrauma is one of the major problems in public health service, which requires more effective therapies and diagnosis [6, 7].

The small volume intracranial hematoma and contusion foci are the urgent issues in neurosurgery. Without being early diagnosed, these brain injuries can cause other potentially serious complications and consequences of «brain concussion», or become the object of active surgical tactics, which often results in additional trauma on the brain [8].

The specialized laboratory tests in correlation with clinical manifestations provide an accurate assessment of the hematoencephalic barrier breach and the damage to the brain. When the cells of the central nervous system are destroyed or damaged, the concentration of certain substances in blood plasma and liquor increases. Their synthesis occurs in neurons and various types of glial cells. The following substances are of most considerable interest in this regard: neuron-specific enolase (NSE) – a neurospecific marker that belongs to the intracellular enzymes of the central nervous system and is the only currently known standard marker of all differentiated neurons. In conditions referring to the involvement of nervous tissue in the pathological process, qualitative and quantitative characteristics of this protein in the cerebrospinal fluid or serum provide valuable information about the severity of neuronal damage and the loss of blood-brain barrier. The enzyme activity NSE increases with the spread of the pathological process on the brain membranes compared with damage to only the brain parenchyma. In several experiments determining enolase by solid-phase enzyme immunoassay in CSF, there has been found a significant increase of it in patients with severe traumas [9, 10, 11].

Glial fibrillary acidic protein (GFAP) is a specific component of astroglial cytoskeletal cells, having a molecular weight of 50 kD. In experiments on rats, there have been determined the relationship of disruption of BBB permeability with the concentration of GFAB in the blood. According to V. A. Berezin, the intake of GFAB in the blood has a two-phase character, both in mild and severe craniocerebral injury. The first maximum is observed after 4 hours after injury, the second – after 24–28 hours, the changes in concentrations being more pronounced in the case of severe trauma, which reflects the nature of the astrocytic reaction in response to traumatic CNS damage [12, 13, 14].

Prevalence rates of traumatic meningeal hematomas vary between 3.0 and 18.2 % among all brain injuries [1, 8, 15]. Current experience of MRT and CT allows determining the quantitative characteristics of hematoma, the timing of hematoma formation, its localization and type, the severity of the brain injury [2, 4, 16]. In recent years, the current concept for the treatment of small volume hematomas (20–50 ml) has tended to avoid surgery. A differentiated (surgical or conservative) approach to the treatment of such hematomas has become possible, taking into account not only the volume but also the localization, since some hematomas resolve over time, leaving no signs of the volume increase which is confirmed by repeated CT, MRI data [3, 4, 16, 17, 18].

The essential criteria for conservative therapy are:

1. The patient's condition of subcompensation or moderate clinical decompensation.
2. State of consciousness in the range of moderate or severe obtundation (Glasgow Coma Scale score of no less than 10 points), reversible state of sopor being allowable.
3. No clinical signs of brain stem shift.
4. The volume of intracranial hematoma or crushing injury focus (according to CT or MRT data) is less than 50 cm^3 for frontal localization and less than 30 cm^3 for temporal localization; the allowable hematoma diameter is less than 4 cm.
5. No visible CT or MRT signs of lateral (midline structure shift is less than 5 mm) or axial (the basal cisterns are not or slightly damaged) herniation.

Thus, the main points are to be considered:

– The severity of the patient's condition.
– The level of consciousness.
– The total volume of focus (the hematoma volume being one of the parameters component).
– Brain shift syndrome.
– Cerebral edema and brain stem symptoms and signs.

One of the most critical issues of neurotrauma in the era of evidence-based medicine is the control of treatment and reflection of the dynamics of pathological processes. CT-examination and MR-tomography are the essential examination methods allowing visualizing and characterizing the pathological focus, to detect the stages of morphological changes, which is of particular importance for the early diagnosis and precision treatment in patients with contusion foci and intracranial hematomas of small volume [3, 8, 16].

The possibility to avoid surgery in some patients, receiving conservative treatment, can reduce disability and prevent complication rates. The effectiveness of non-drug therapy, along with medications, is more broadly recognized in current clinical practice. Laser treatment is a widely used therapy nowadays [19, 20, 21].

Laser therapy is the use of low-intensity optical emission laser within the medical field. LASER stands for Light Amplification by Stimulated Emission. A laser emits light, which is monochromatic and coherent. This means it generates light at one particular wavelength only, and all emitted light waves are in phase with each other. It has the narrowness of the beam (high directivity) and fixed direction vectors of the electromagnetic field (polarization). Laser irradiation (LI) affects biological tissues. The effect of low-intensity laser irradiation on the biological object is as follows: the effect of laser on tissues results in photophysical and photochemical reactions, mediating light absorption and disruption of weak molecular bonds, perceiving and transfer of it by body liquid media. There have to be noted additional effects referring to adaptive and compensatory response, which is metabolic activation of cells [22, 23, 24, 25].

O. P. Galeeva and co-authors (1995) reported on the treatment of patients in a deep coma due to severe traumatic brain injury, using intra-arterial blood irradiation with helium-neon laser (light guide was introduced through the lumen of the superficial temporal artery to the level of bifurcation of the common carotid artery). A. Khelimsky, V. V. Germanovich and co-authors (1996) used helium-neon laser intraarterially (internal carotid artery) in the complex treatment of severe craniocerebral trauma [26]. Yu. A. Zozulya and co-authors (1989) applied intravascular laser irradiation of blood in the postoperative period in patients with various neurosurgical pathology (craniocerebral trauma, tumors, vascular diseases). However, intravascular irradiation of blood is accompanied by the risk of invasive complications, additional pain reception, the need for disposable infusion droppers and light guides, possible damage to blood cells [27]. In the acute period of mild traumatic brain injury A. O. Korkushko and co-authors (1995) used an IR laser with a wavelength of 0.89 µm in continuous and pulsed wave modes [28]. According to I. Z. Samosyuk and co-authors (1996), for the treatment of traumatic encephalopathy and normalization of liquor dynamics, an infrared laser was applied transcranially [29].

Currently, helium-neon lasers (HeNe laser) with a wavelength of 0.63 µm are being replaced by portable compact semiconductor lasers capable of inducing radiation in this region of the spectrum. Semiconductor lasers are small, relatively easy, and safe to operate. They are block-structured, allowing the use of different wavelengths and types of exposure. Semiconductor devices can be used directly at the patient's bed in compliance with the principles of a therapeutic and protective regimen. The choice of visible red radiation is not accidental and pathogenically justified. Erythrocytes as porphyrin-containing cells are acceptors (chromophores) of laser radiation in the red region of the spectrum. This largely explains the positive effect of the 632.8 nm NILI on the rheological properties of blood: a decrease in erythrocyte aggregation and an increase in the ability of red blood cells to deform due to changes in their physical and chemical properties [30, 31, 32].

The activation of photobiological processes, occurring during selective absorption of laser radiation, causes the expansion of microcirculatory vessels, normalizes local blood flow and leads to dehydration of the focus. Reparative processes in tissues are activated. The inclusion of laser irradiation of blood in the treatment for brain injuries is a pathogenically justified mechanism aimed at stimulating microcirculation and reparative processes in the nervous tissue [33, 34].

S-100 is the astrocyte-specific glial protein, located in the brain tissue in a calcium-binding state. The S-100 family of proteins consists of 17 tissue-specific monomers, two of which form homo and heterodimers containing two identical or different polypeptide chains, each of which has two CA-binding sites. Different types of proteins of the S-100 family are found in the cytoplasm of different cells (neurons, glial cells, epithelial cells, heart and skeletal muscle, placenta), as well as in the extracellular space. Their functions are diverse and involve the regulation of the activity of many enzymes, assembly and disassembly of cytoskeleton elements, participation in the control of exo- and endocytosis, functioning as a kind of growth factors. Increasing S-100 concentrations in CSF and plasma is a marker of brain injury, and protein concentrations reflect the severity of the brain matter damage. The level of S-100 significantly increases with age, and to a greater extent in men than in women [35, 36, 37].

Myelin essential protein is released in CSF in any damage to the nervous tissue. It's level increases in injuries of the nervous system, tumors, multiple sclerosis, viral encephalitis, and other neurological disorders. In regular liquor, it is virtually absent (its concentration does not exceed 4 mg/l) and appears only in pathological conditions. This laboratory sign is not specific for certain nosological forms but reflects the size of the lesion (mainly associated with the destruction of white matter). It has been found that in the acute period, patients with craniocerebral trauma, serum levels of OBM dynamically increased [36, 37].

Along with immunochemical studies, biochemical parameters of blood and liquor are of considerable interest. It has been found that the level of α2-macroglobulin (a2-MG) in liquor correlates with the severity of brain tissue injury. Typically, α2-MG in the CSF is practically not determined, because due to the sizeable hydrodynamic radius of the molecule, it does not penetrate through the BBB. With the minor head injury referred to as concussion, a minimum content of α2-MG has been found in liquor. The level of a2-MG in the cerebrospinal fluid is higher in moderate brain injuries accompanied by the death of damaged areas of the brain and pronounced neurological symptoms. In patients with severe brain damage (severe brain injury, compression of the brain by hematomas), the amount of α2-MG in liquor is 4–11 times higher than its content in the cerebrospinal fluid of the control group [38, 39].

In addition, taking into account the important role of antioxidant systems, it is pathogenetically justified to control the activity of its enzymes (superoxide dismutase and catalase).

Conclusions. Based on the above stated, we can conclude that traumatic brain injury accompanied by contusion foci and intracranial hematomas of the small volume is an important and not yet solved problem since in this group of patients, there is a significant potential for improving the recovery process and restoring the quality of life. Laser therapy is a promising regenerative-reparative method for the treatment of pathogenetic processes underlying traumatic brain disease. The principal components of an integrated diagnostic and curative strategy in patients with brain contusions should be both methods of computer and magnetic resonance imaging and laboratory studies to determine the degree of damage to the nervous tissue.

Disclosures:
The authors declare no conflict of interest.

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