

# Laser Technologies in the Treatment of Ischemic Stroke

## Editorial

The brain is the most vascularized organ - It contains from 3 to 4 thousand capillaries in one cubic centimeter of cerebral tissue, which is significantly higher than that of any other human organs and tissues. This need of cerebral tissue for high capillary blood flow leads to the fact that the slightest disturbances in blood supply cause impaired tissue metabolism, development of hypoxia, and death of mitochondria in neurons, ischemia and stroke [1].

The number of ischemic strokes is constantly increasing all over the world leading to high mortality and disability of the population. This state of affairs requires development of new, highly effective methods of treating and rehabilitating stroke patients. The treatment of ischemic stroke should be pathogenetically substantiated, comprehensive, aimed at improving and restoring blood supply, restoring metabolic processes, synthesizing adenosine triphosphate (ATP) in the mitochondria of neurons, and regenerating cerebral tissues.

One of the most promising areas in the treatment of ischemic cerebral strokes is the use of laser technologies, which currently has two directions:

- Laser with low output power, by means of which various types of Photobiomodulation Therapy (PBMT) are carried out. Currently, laser PBMT in cerebral lesions is divided into: transcranial [2-5], intranasal (often in combination with transcranial) [3-5], intravascular (intravenous) [6] and trans catheter intracerebral methods of treatment [7].
- Laser with high output power, which is used to conduct Percutaneous Trans luminal Laser Angioplasty (PTLA) [8-10].

For PBMT, laser systems operating in the red and near-infrared (NIR) range of the light spectrum (600-1100 nm) are used [2]. When carrying out any PBMT methods, the use of these light energy sources does not cause damage to brain tissue [7-9]. In the red and NIR

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spectral ranges, cerebral tissues do not absorb much laser energy. Low absorption leads to a sufficiently large depth of penetration of laser energy, which is extremely important when conducting PBMT, as it allows to affect not only the irradiated surface, but also more deeply located tissues. With a direct effect on the brain, the depth of light penetration in the red range is from 20 to 40 mm, in the near-infrared range it is over 50 mm [4-9].

The mechanism of therapeutic effect when using laser with low output power of the red and near-infrared spectral regions is complex.

It means stimulating angiogenesis, which causes collateral and capillary revascularization of ischemic cerebral tissues, improving cerebral tissue oxygenation, stimulating and restoring ATP metabolism in neuron mitochondria, restoring tissue metabolism, restoring synaptic connections, stimulating neurogenesis and regenerating damaged tissue [2-5] [7-9]. The transcranial PBMT method implies the effect of laser energy on the

brain through the scalp and skull using special light-guiding devices and helmets for this purpose, which allow affecting large surfaces of the head [2,4]. The method is applied in courses, it is effective, easy to use, and it can be carried out even at home. The degree of laser energy penetration into the head could depend on the area of the skull that is exposed, since the skin and bones absorb light energy differently. At a wavelength of 830 nm, depending on the specific area of the head, the penetration of light energy ranges from 0.9% to 11.7% [2-5].

The intranasal PBMT method is aimed at bringing laser energy closer to the brain tissue. This method is often combined with transcranial PBMT. The easiest method which can be used at home is Intranasal PBMT from the Nostrils. It means bringing an additional source of laser energy through the nostrils. More complex methods that require surgical intervention include Intranasal PBMT from the Nasal Cavity and from the Nasal Sub mucosal Space and Intranasal PBMT from the Sphenoid Sinus [3,5]. The intravascular (intravenous) method is also a simple, minimally invasive method. In fact, this method is intravascular laser irradiation of blood (ILIB). A helium-neon laser (wavelength 632.8 nm) is used as a source of laser energy. When it is carried out, blood is exposed to laser through a peripheral intravenous catheter. There is no direct effect of laser energy on brain tissue.

According to the authors, the method has a good clinical effect in patients who have had their first ischemic stroke. All treated patients showed faster rehabilitation with recovery after the stroke. The mechanism of the effect of ILIB on the brain is not completely clear; however, the authors indicate that, according to single-photon emission computed tomography (SPECT), the laser exposure increases regional cerebral blood flow, which improves motor, sensory, and cognitive recovery. To obtain a stable clinical effect, at least 10 sessions are required [6]. Trans catheter intranasal PBMT is a more complex method, which is carried out in hospital. The method means endovascularly conducting laser energy with the help of thin flexible fiber-optic instruments in the distal sections of the cerebral vascular bed directly to ischemic cerebral tissues in the area of stroke development [7-9].

To determine the localization of the cerebral atherosclerotic lesion that caused the stroke, the patient undergoes cerebral multi-gated angiography (MUGA) in

the catheterization laboratory, according to the results of which the affected vascular branches are singled out. Laser exposure is performed in a catheterization laboratory. Under local anesthesia, the common femoral artery is catheterized with an introducer. Guiding catheters are conducted through this introducer under fluoroscopic control and are sent to the intracerebral branches. Through these catheters, a flexible fiber optic fiber guide instrument with a diameter of 25 to 100 micrometers is coaxially held. A fiber optic instrument is conducted to the area of the developed stroke, where the laser action is performed. Typically, PBMT is carried out using a continuous helium-neon laser with a wavelength of 632.8 nm [7-12].

After trans catheter intervention, repeated cerebral MUGA is performed, according to the results of which, the severity of intracerebral angiogenesis, collateral and capillary revascularization is judged. The method avoids the loss of laser energy when passing through various media and tissues of the skull, since light exposure is directly on the affected cerebral sections. Trans catheter intervention is performed once and does not require repeated sessions. Unlike the laser with low output power, the laser with high output power can damage biologic tissues, both at the site of exposure and in deeper layers. In this regard, the methods of their application have their own specifics, based on the selective, local destruction of some biological tissue that has a high degree of absorption of laser energy of a certain wavelength [8,9].

Percutaneous Trans luminal Laser Angioplasty (PTLA) is aimed at destroying atherosclerotic tissues that occlude arterial vessels using laser with high output power and at restoring the main blood supply to the ischemic region<sup>8</sup>. The specificity of this method is that during the destruction of atherosclerotic tissues, the vascular wall and surrounding tissues should not be damaged<sup>8-12</sup>. Typically, for PTLA extra and intracerebral vessels, a solid-state YAP is used: Nd laser (LiYO<sub>3</sub>), operating in a pulsed mode in the green region of the spectrum, the wavelength of 539 nm, the pulse energy of 6-9 mJ, the pulse repetition rate of 3-6 kHz [9,10].

Using this type of laser is due to the high degree of absorption of laser energy at a wavelength of 539 nm by atherosclerotic tissues. At the same time, the intimal and muscle layer of the vascular wall absorbs laser

energy of this type in a much lesser extent, which does not lead to their destruction. When using the non-contact method, selective destruction of atherosclerotic tissues occurs. Similarly, as with trans catheter intranasal PBMT, to determine the localization of the atherosclerotic lesion that caused an ischemic stroke, a diagnostic multi-gated angiography (MUGA) is performed in the catheterization laboratory. When performing PTLA, a fiber optic instrument with a diameter of 100-200 micrometers is non-contactly passed to the site of the arterial occlusion, where laser destruction of atherosclerotic tissue is carried out.

After the PTLA, repeated cerebral MUGA is performed, the results of which determine the degree of restoration of arterial blood flow [8-10].

In conclusion, it can be justifiably said that PBMT and PTLA are highly effective, physiologically sound methods for the treatment of ischemic stroke, and they are highly important in modern neurology and laser medicine. These methods easily tolerated by patients, they can significantly reduce the mortality and disability of I patients who have had an ischemic stroke, accelerate rehabilitation and lead them to normal everyday life.

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