SOME ASPECTS OF MEDICAL APPLICATIONS OF LASERS

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Some basic principles of medical applications of lasers are considered. It is shown that a low–intensity radiation of a Cu–vapor laser at the wavelengths $\lambda = 510.6$ nm *and* $\lambda = 578.2$ nm *can affect tumor processes. A comparative clinical data on the laser therapy effects of a He–Ne laser radiation and radiation of a Cu–vapor laser on the stomach ulcer are presented. Clinical data have been obtained from numerous observations. The best therapeutic effect has been observed in the case of patients with chronic callous ulcers.*

A history of optical quantum generators (lasers) has entered its third decade. The range of laser applications extends rapidly covering new and new areas so that such terms as laserology, laser medicine, and laser therapy are quite usual now.

The verity of the opinion of one of the quantum physics fathers, the Nobel prize laureate, A.M. Prokhorov that laser would find its basic applications in biology and medicine, is now proved. Nevertheless, poorly studied mechanism of a laser beam action on organs and tissues is a central problem of medical applications of lasers. The radiation wavelength, absorptivity of tissues, dose, and exposure time are the most important factors which determine the result of a laser–beam and tissue interaction. Therefore, the lasers are applied to medicine following such directions as:

(a) laser surgery (laser coagulation and laser scalpel),

(b) laser diagnostics (photodiagnostics, photochemical diagnostics, and optical and acoustic holography), and

(c) laser therapy and photochemotherapy.

1. Laser coagulation and laser scalpel hold a central position in surgery. The thermal effect is claimed[1,2] to play an important role in the mechanism of powerful–lasers action. Experiments have proved the dose–dependent molecular–kinetic changes in tissues occur under the action of laser radiation due to light absorption, leading, as a result, to temperature runming. Temperature peaks up to several hundred degrees are possible in tissues that cause changes like a thermal burn. In other words, laser beams cause not only the dose–dependent heat and coagulation but vaporization of tissues as well, what, in fact, makes a cut.

The cut quality also depends on the laser radiation wavelength. A CO_2 laser operates in the far–IR region 1060 nm. High absorption by water and low scattering in tissues of its radiation is favorable for its use to cut tissues. A CO_2–laser scalpel is now widely used in surgery. Green light of the Ar–ion laser (514 nm) can be absorbed by hemoglobin and, thus, is suitable for activating the blood coagulation. An Nd–laser radiation (1060 nm) is also a good coagulator. Its ability to cut is lower because of higher scattering. Recent trends are toward the use of coagulative property of laser radiation in endoscopic therapy. Pantsyrev[3] has reported a successful clinical application of a copper–vapor laser (510 nm) to coagulation of stomach hemorrhage. The coagulative destruction of tumors is primarily employed in bronchology, ophthalmology, urology, as well as for treating skin tumors.

2. Laser photodiagnostics is based on radiative phenomena (fluorescence and phosphorescence), which arise in a molecule irradiated by laser radiation. Photodiagnostics is normally used to detect a desease since in an ill tissue there occurs accumulation of substances which are absent in a healthy tissue.

Photodiagnostics (sensitized photodiagnostics) needs for use of dyes which can be deposited in tumor cells. Such vital dyes are normally used as eosine, hematoporphirin, acridin, methyl blue, and others. After exposing, the tumor cells to a laser beam one can detect the fluorescence on a body surface or inside it by means of an endoscopic technique.

Holography (laser photography) is a three–dimensional image of an object exposed to laser radiation. By means of optical holography the human body surface can be investigated, and the endoscopic technique is used in studing the interior of hollow organs. Acoustic golography is applied to study the tissues and organs, which are difficult to be observed directly. The diagnostical role of holography, especially of the acoustic one is very promising.

3. Laser therapy and photochemotherapy are used to stimulate the biological processes as well as to destruct cells and tissues. Ruby (694 nm), He–Ne (633 nm), and Ar–ion (514 nm), as well as Cu–vapor (510 nm) lasers are applied to:

– general irradiation of a human body,

– intravenous irradiation of blood,

– local irradiation of a region of pathological process or acceleration of wound healing, and

– irradiation of biologically active points and reflexogenic zones.

A He–Ne laser is the most widely used because of its availability[4,5] (it is a commercial type of lasers, several models of medicine purpose among them exist), relatively low prices, and operational symplicity. The monochromatic red light with the wavelength from 630 to 650 nm is also noted as possessing stimulator properties, characteristic, in particular, of the hormonal stimulation: it favors to phagocytosis increase, function of reticuloendothelial system, change of the surface potential of cells, and creation of negative ions. The low–energy

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lasers, the power of which fails to destruct a molecule, only break intramolecular chemical bonds, thus changing its activity. As a result the molecule state becomes excited that initiates different photochemical changes as, in particular, the creation of free radicals characterized by high reaction power and capability to act as activators of a number of ferments, which assist in yielding up and utilizing the energy of bilogical processes.

Laser irradiation effect can be enhanced by simultaneous use of chemical matters. In this case we deal with photochemotherapy. Photodestruction takes place when a biomolecule absorbs a photon, the energy of which causes the molecular ionization or excitation. This results in disturbance of bond forces, the molecule decay and the cell destruction. In clinical practice a nitrogen laser is normally used for photodestruction of tumor tissue; ruby and argon lasers can be used for this purpose as well.

Photochemical destruction (biochemical photodestruction) is based on photodynamical action of dyes on tumor cells, in which the radiation causes oxidation processes. The dyes used here are the same as in photochemical diagnostics. They can be put on a surface of a tumor, injected inside it, or inserted parenterally. Then the tumor might be exposed to the visible or UV radiation. It should be noted that the UV radiation produces better effect.

In recent years more and more new therapeutic instruments are designed based on a He–Ne laser. Thus, medical therapeutic laser instruments "Laster–03", "Laster–04", and "Laster–05" being successfully used in clinics of Tomsk, Barnaul, Kemerovo, Vladivostok, and other cities, we have developed in cooperation with our collegues from the Design–Technology Institute "Optika" of Siberian Branch of the Russian Academy of Sciences.

Semiconductor lasers begin to compete with the He–Ne lasers due to their lower prices and easier functioning. A great deal of works[7,9,10] are available now, in which efficiency of these lasers is underlined when treating a diversity of pathologies.

Metal–vapor lasers, as, in particular, Cu–vapor ones are less studied sources of radiation from the standpoint of their action on a human body, because they are not so widely spread (not commercial), expensive, bulky, difficult in operation (many of them need water–cooling).

Experimental data by T.I. Karu show the Cu–vapor–laser radiation (578 nm) of 0.1–0.3 J/cm^2 power density to be the best stimulator of RNA synthesis and, consequently, to be able to increase the rate of protein synthesizing and stimulate the wound healing.[8]

Physicians of Tomsk, Moscow and St.–Petersburg were among the first medical scientists who began to use the Cu–vapor laser in experimental and clinical practice. In 1982 we investigated the action of a Cu–vapor laser radiation on the microflora of suppurative wounds. A more pronounced inhibiting action of the Cu–vapor laser radiation compared to that of a He–Ne–laser radiation had been noted. During the next 5–6 years there were a great deal of experimental studies of laser radiation action on the growth of tumor and metastasis.

The obtained results have shown that radiation of different wavelengths produces different biological effect depending on the laser parameters. Thus, for example, a radiation from a He–Ne laser stimulates the tumor growth while radiation from Cu–vapor laser suppresses the tumor and metastasis growth. Radiation at 510 nm was noted to stimulate regeneration of wounded skin and simultaneously to suppress the tumor and metastasis growth of the tumor animals. The best effect was obtained at 1 J/cm^2. Dye laser radiation with Cu–vapor laser pumping at a wavelength of 633 nm stimulates the tumor formation. Results of these investigations allowed us to use a Cu–vapor laser for treating the suppurative inflammations accompanying cancer deseases as well as treating the inflammations arised as after–effect of operations of cancer patients, to which many physiotherapy treatments were contra–indicated.

Clinical investigations conducted during 1985–1988 at the Tomsk Oncological Scientific–Research Institute showed that Cu–vapor–laser therapy is efficient in the case of pleura empyema and suppurative endobronchitis at the radiation dose of 0.1–0.2 J/cm^2 in 3–5 seances. Treatment of stomach ulcer as a predecessor of tumor and erosive–ulcer after–effects of stomach resection occured to be efficient at a dose of 6 J/cm^2 and in 7–10 seances.

Good results were obtained with a Cu–vapor laser for profylaxis and treatment of the after–radiation effects. We have proposed a method for treating wet dermatitis caused by neutron exposure in which the yellow–green spectrum is used in a Cu–vapor–laser. A laser beam irradiates an affected portion of the skin using an optical waveguide. The radiation treatment is conducted by successively exposing the regions, the number of which is a function of the radiation–damaged area.

Endoscopy is now a central application of the Cu–vapor lasers. We present results obtained when treating the stomach and duodenal ulcers. There were 64 patients in the group under study, 65% of which had ulcers for more or less long time resisted the drug treating during 3 months. 70% of patients had been ill for more than 3 years, and others for more than 10 years. Half of the patients had an ulcer area from 0.5 to 1.0 cm and 30% of them more than 1 cm in diameter. 42% of patients had the stomach ulcer, the rest of them had the duodenal ulcer.

An LG–75 He–Ne laser and a Cu–vapor laser were used in endoscoping. To compare the efficiency of the treating, a common dose of 1–3 J/cm^2 per focus was taken as the basic one (the method by Koshelev[11]).

The results confirm high efficiency of laser radiation in treating the stomach and duodenal ulcers. About 65% of ulcers exposed to a He–Ne–laser radiation and about 80% of ulcers exposed to the Cu–vapor laser radiation were covered with epithelium. In both cases the defect healing had resulted in a pink scaring and folds converging without deformation of organs. The radiation–exposure seances were performed in a day. As a rule the effect could be observed already by the third seance. The rate of ulcer scaring was a function of its size. The treating course lasted from 4 to 7 seances.

The analysis of the results obtained allowed us to arrive at a conclusion that the ulcer size was of fundamental importance for both types of radiation. It should be noted that the Cu–vapor–laser radiation is more effective in the case of large callous ulcers. These results are in good agreement with data of the Central Gastroentherology Institute.[12]

An increasing interest of physicians and investigators to the laser medicine should be noted in conclusion. A proper choice of energy parameters of the laser exposure depending on the area–damaged size, exacerbation time, and localization, is an urgent problem along with the problem on permissibility of applying the laser radiation in combination with medicinal or other means. This is so because no unified concept on the mechanism of the laser radiation influence on a human body as a whole and on its individual systems and pathological foci exists at present.

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