Photon Irradiation Device for Antimicrobial Therapy

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***Abstract* - A device for a procedure for preoperatively preparing patients with progressive drug-resistant fiber-cavernous tuberculosis also for treatment of other diseases, as lungs and other organs is developed. The device performed process of treating infected cavities and contains: mercury tube, focusing system for selection of segment of the radiation spectral band 250-500 nm, optical guide with connectors and a puncture needle. Use the tube with high pressure mercury vapor as a radiation source allows to obtain the broadband photon radiation for treatment more efficient and for recovery time reduce. It also provides a substantial simplification of the device and reducing its costs. The device was used to approve the method of treatment of infected cavities by means of endocavitary broadband irradiation. In the experiments we used cultures of Escherichia coli and Candida albicans. Effect of annihilation of bacteria colony is almost directly proportional to the duration of exposure and complete suppression occurs within 2 min.**

I. INTRODUCTION

One of the most difficult issues of the modern medicine is the combat against the infectiuos diseases. At the same time the problem of the increasing resistence of the infected microorganisms against the most up-to-date antibacterian preparations (the chemotherapy problem), is becoming more urgent. Because of this we propose to develop a device for photosanitation with ultraviolet C radiation of the human cavites populated with colonies of unspecific or/and tuberculosis microflora. Ultraviolet laser technologies used in the treatment of destructive forms of tuberculosis begin their history with the development and utilization of ultraviolet laser with nitrogen as the working substance (medical installation "Almiţin" with wavelength $\lambda = 337\,nm$ developed in 1995 under the management of Nobel laureate Academician Prokhorov A.M.). This installation has been made in small series in Russia (Samara) and has been used successfully in Central Institute of Tuberculosis (Moscow), clinic Chytram (Indore, India) and University Hospital Blumfonten (South African Republic) on treatment of more than 1500 patients. Currently, this device is no longer produced. In the process of supplementary investigations have noted that the maximum photosanitation effectiveness of tuberculosis caverns occurs when using ultraviolet from region C (240-280 nm), with the absolute maximum efficiency for $\lambda = 254.6\,nm$. From these considerations has been developed device "Amulet" with the wavelength $\lambda = 266\,nm$. This wavelength is achieved by multiplying the frequency of neodymium laser radiation $\lambda = 1064\,nm$. Mass production of the installations with 266 wavelength has not been made because of high cost and low power obtained in the flow of radiation (5mW) [1].

The main component of the installation "Maria" is KrF excimer laser, which generates pulsed laser radiation with wavelength 248 nm and frequency of 100 Hz. By using an optical system, radiation is admitted to the end of a sterile single-use optical fiber inserted through . an cavernous pulmonary micro drainage.

Namely this installation is currently used at the Central Institute of Tuberculosis ASM FR, where was developed the method of photosanitation of pulmonary cavities in fiber-cavernous tuberculosis cases [2,3], which is the most dangerous clinical form of this disease from epidemiological point of view . As noted in the published studies, photosanitation of lungs cavities reduces the number of resistant and multi-drug-resistant tuberculosis forms, helping to improve the situation of tuberculosis evolution overall.

The mechanism of DNA molecules modification consists in forming in them, under the action of photons, of thymine dimmers by saturating the covalent connections between two neighboring bases [4].

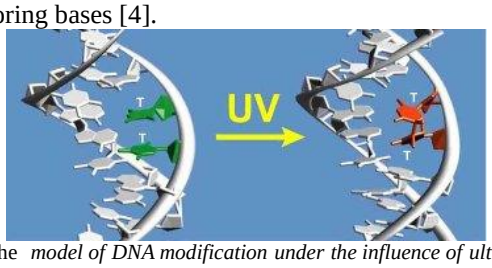

Fig.1 The *model of DNA modification under the influence of ultraviolet radiation*

To note, that speed of DNA destruction is very high. Recently [5] has been demonstrated that the reaction of dimerization of the thymine (pyrimidine $C_5H_6\,N_2O_2$) under the action of ultraviolet radiation takes about 1 pcs (10-12 sec). Acumularea acestor modificări de structură în ADN microorganismelor cauzează micşorarea vitezei de reproducere a microorganismelor şi, deci, anihilarea lor.

The researches performed demonstrates that for different representatives of nonspecific microflora, lethal doses are different. Liveness and lethal doses at wavelength 248 nm for 5 initial strains: *Pseudomonas aeruginosa, Escherichia coli, Enterobacter aerogenes, Klebsiella pneumoniae and Staphylococus aureus* are reprezented in Pic. 2[6].

We mention the varied sensitivity of different strains at ultraviolet laser emission energy. The most sensitive strain is *Staphylococus aureus* with letal dose $3\,mJ/cm^2$, and the most resistant *Enterobacter aerogenes* – 7 mJ/cm^2.

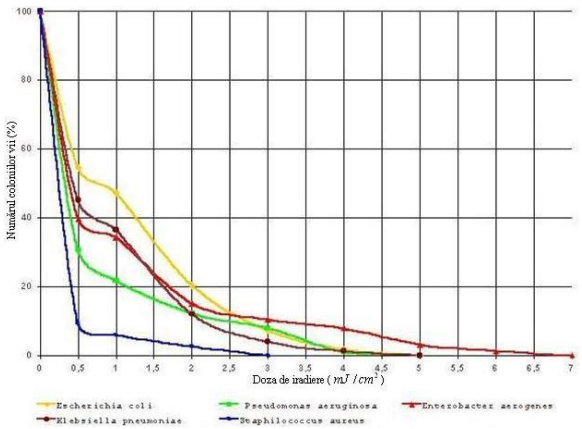

Fig.2 *Dependence, dose - liveliness, at bacteriostatic action of laser radiation of wavelength 248 nm, on the nonspecific microflora*

How we see from dependence of the number of colonies that survive the radiation dose of irradiation, for wavelength 248 nm , the absolute lethal dose is 8-10 mJ / cm^2 .

In particular, we mention the absence in the specialty literature, of the genetic modifications evidences of the human body cells under the action of ultraviolet radiation C [7,8].

II. DEVICE FOR PHOTOSANITATION OF THE INFECTED CAVITIES OF THE HUMAN BODY

The proposed objective is to perform the necessary investigations and developing a photosanitation device with ultraviolet radiation C of the human body cavities populated by non-specific microflora colonies and / or tuberculosis.

These investigations and the development of antimicrobial irradiation devices are necessary because of the permanent growth of the pathogenic flora resistance to antibiotics [9].

From all the information, that we possess, is not apparent the necessary of coherence ultraviolet radiation in order to destroy the bacteria. Basically, as a radiation source could be LEDs. We have developed and manufactured an irradiation module with LED T9F25C (Optodevice Co. Seoul., Ltd.) [10]. But currently the produced LEDs by (Seoul Optodevice Co.., Ltd., Photon Systems, Inc. and others) which are radiating in region C have an insufficient optical power emission.

From what is known, mercuric lamps have a very strong sterilization action, the character of their radiation not being coherent. Important is, firstly, the wavelength of the photon (i.e. energy), intensity and duration of irradiation.

From these reasons, the device of fotosanare with ultraviolet radiation C of the human body cavities populated by non-specific microflora colonies and / or tuberculosis, as a source of radiation serves the discharge in arc in the mercuric tube at high pressure. This way, we eliminate the most expensive element from structure of the irradiation device - the laser / LED. The use as a source of the radiation the mercury tube at high pressure, allows more efficient treatment method by increasing the band used in the process and achieve a device that generates the wavelength band 250-500 nm with the possibility to select spectral segment of the radiation.

The wide band radiation in addition to the pronounced bacteriostatic effect, exercise a stimulating action on microcirculatory processes in irradiated area, resulting at more efficient treatment and reducing the period of healing the patient. The device for treating the infected cavities, using wide band photon irradiation method consists of: tube of mercuric steam 1, quartz condenser 2, the shutter 3, the spectral radiation selecting device 4, optical connector 5, optical guide 6, optical connector 7, the distal segment of the optical guide 8, punction needle 9, power supply unit 13, which through the power stabilizer 10 supplies tube 1, timer-dozer 11 (which drives the shutter 3) and measuring device of the radiation power injected into the optical guide 12, photoreceptor 14 assembled with the optical connector 15

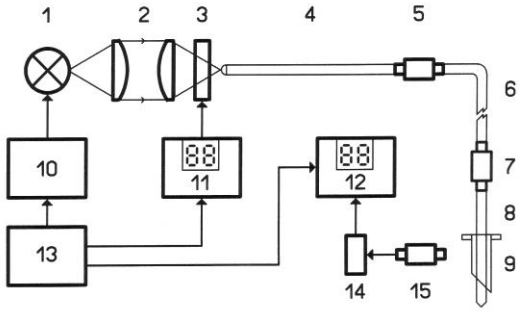

Fig. 3. Block diagram of the photosanitation device

Using the tube with the high pressure mercuric steam as a radiation source allows obtaining a wide band photon radiation, substantially simplifying and reducing the device's cost.

III. IRRADIATION PROCEDURE AND RESULTS

The device for treating the infected cavities with wide band photon irradiation method was made and used to approve the method of infected cavities treatment through wide band endocavitary irradiation method.

The experiments were performed in laboratory of medical diagnostic and laboratory of microbiology at the Institute of Phthisiopneumology, virology and immunology at the Faculty for training doctors at Medical University "Nicolae Testemitanu" researching the in vitro the influence of the wide band radiation on the different bacterial strains. The radiation parameters have had the following values: optical power at wavelength 254 nm - 1mW, and in range 280-500 nm - 15mW. In the experiments were used cultures *Escherichia coli* and *Candida albicans*.

Were performed 10 inseminations and from obtained cultures were prepared suspensions following standard technologies. In Petri dishes with agar - blood have been dropped 0.1 ml of suspension with a concentration 10^6 microorganism in $1cm^3$ of solution. Petri dishes thus prepared were exposed to 10, 20, 30, 40 s and 1, 2, 3, 4, 5 min. Were irradiated sectors with $1cm^3$ areas, leaving the non-irradiated sectors for comparison between the exposed sectors. Petri dishes were incubated 24 hours in thermostat at the temperature of 37^0C. The calculations were performed by an optical microscope with x100 zoom. The results are presented graphically in figure. 2.

How is apparent from the presented results, the effect of microorganisms annihilation depends approximately directly proportional to duration of exposure until, basically, total deletion within 2 min. Not irradiated sectors are covered by a dense layer of colonies of microorganisms.

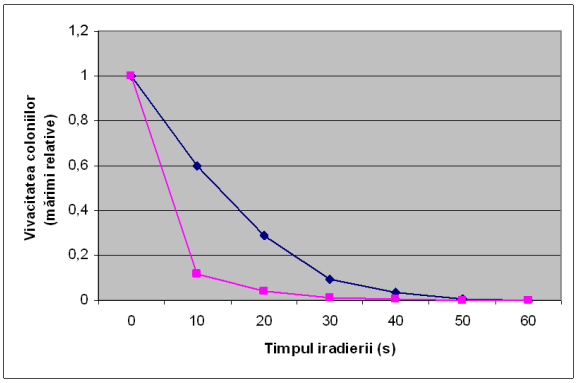

Fig. 4 The dependence of liveness of the Candida albicans colonies and Escherichia coli

Fig. 5 The irradiation results of *Staphylococcus aureus* bacterial colonies grown on agar - blood (irradiation time = 15,45,60s and 2,3,5 min)

These results are above those obtained through the monochromatic irradiation using laser device [1,2].

In conclusion, the method and device proposed, allow quick removal of the pathogenic microorganisms populations from the wounds and infected cavities, rising - thus, the speed and efficacy of treatment.

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