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Organization Of The Structure And Principles Of Functioning Of The Biotechnical System Of Safe Human Body Light Exposure.

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ABSTRACT

One of the topical tasks of human healthcare is the performance of preventive, therapeutic and rehabilitation measures for completion of light starvation caused by a set of natural, anthropogenic and social factors. In order to minimize the losses, artificial sources are used to form the emission spectrum close to natural sunlight. The impact of light exposure on the human body can be both positive and negative. It depends on the choice of spectral components of radiation, their intensity and exposure time. Human skin is especially sensitive to the ultraviolet component, which can cause both effectively positive and significantly negative impact. To minimize the negative effect of the process, it is necessary to control the impact and radiation dose, taking into account the individual characteristics of human skin. Creation safety light irradiation (dosed and controlled) possible thanks to management of means of technical support. The article suggests the union of modern technology base, including means of influence and intellectual support for monitoring and control of processes with the principles of the biotechnical systems design that require mutual adaptation of biological objects and technical equipment, providing an effective solution of the problem. To improve the efficiency and safety of the corrective effect of light on the human body, in the article we suggest the principles of the structure and features of functioning of biotechnical system that takes into account the individual characteristics of human skin erythema to choose correct exposure parameters.

Keywords: skin, light exposure, ultraviolet exposure, safe dose, biotechnical system, LED light source, control erythema, wireless technologies, intellectual support.

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INTRODUCTION

Light exposure energy is an essential component involved in the maintenance of the optimal biochemical, biophysical and physiological processes in the body of each person [1]. The need of the body in the light energy consumption depends on many internal and external factors [2]. It is known that a part of the human population suffers from health problems caused by light starvation [3]. This is especially significant for the professional community which activity is accompanied by light deficiency (mining workers, subway workers, etc.) [4]. This calls for preventive, therapeutic and rehabilitative measures, intended to compensate the light and energy loss of these groups.

Light exposure is carried out through the skin, which is integrated with other functional systems in a whole organism. Studies have shown [5] that the spectral characteristics of solar radiation, which cause a significant effect on the human body and contain spectral components from the infrared to the ultraviolet radiation spectrum. Components of the solar radiation spectrum provide different, mostly positive effects on the human body, the nature of which depends on the radiation dose [6]. A special place takes the ultraviolet spectrum component, which can have a significant positive or negative effect on the skin and the body [7]. At the same time, the negative effect of UV radiation affects the biophysical, biochemical and physiological levels of the organism. The first functional system of the body in the path of the light flux is the skin, which suffers from exceeding the maximum tolerated dose of UV radiation. Such excess causes skin irritation, turning into various degrees of burns, which leads to pathological changes at all body levels [8]. Light and energy loss can be compensated by both natural and artificial means, however, the natural ways of compensation are not always available and are complicated to use the required spectrum, the intensity and duration of light exposure. Modern medicine uses artificial radiation intensively to correct the condition of single organs and tissues and the whole human organism [9]. However, the effectiveness of this correction is low, since it barely takes into account the totality of the factors influencing the determination of the necessary spectrum and radiation dose. Especially topical is the need to minimize the risk of negative impact of UV radiation. In this case, the radiation dose should be determined considering the individual characteristics of human skin as the primary receiver, transmitter, and conductor of light energy.

MATERIAL AND METHODS

To solve the problem of safe (metered and controlled) light exposure it is necessary to create its methodological and technical support. The developed method of forming the radiation parameters considering the individual properties of a biological object (skin erythema of the patient) and the proposed principles of interaction between a biological object and technical means during the impact process [10], based on creating a mathematical model, which relates the impact on biological object and its response to the impact. The estimates of model parameter allow to predict the maximum permissible radiation dose in each case. Implementation of the proposed method is possible with the help of modern technology, including controlled ways of influence and intellectual support of monitoring and control processes.

For the technical realization of controlled light exposure method it is suggested to use the principles of biotechnical system (BTS), which unites the biological object and technical means into a single control circuit for the implementation of the target function [11]. For this purpose, we developed the structure and the basic principles of the BTS functioning, taking into account the individual characteristics of a biological object and forming light exposure in accordance with target setting. Fig. 1 shows the structure of the BTS, which, in addition to a biological object and the specialist (health worker), comprises means for: forming of the light exposure; registration of the parameters of the light exposure; registration of the color characteristics of the skin erythema; audio/video surveillance and communications; wireless connection of informational exchange between BTS units; intellectual support (management, processing, storage, display); interactive communication with the specialist.

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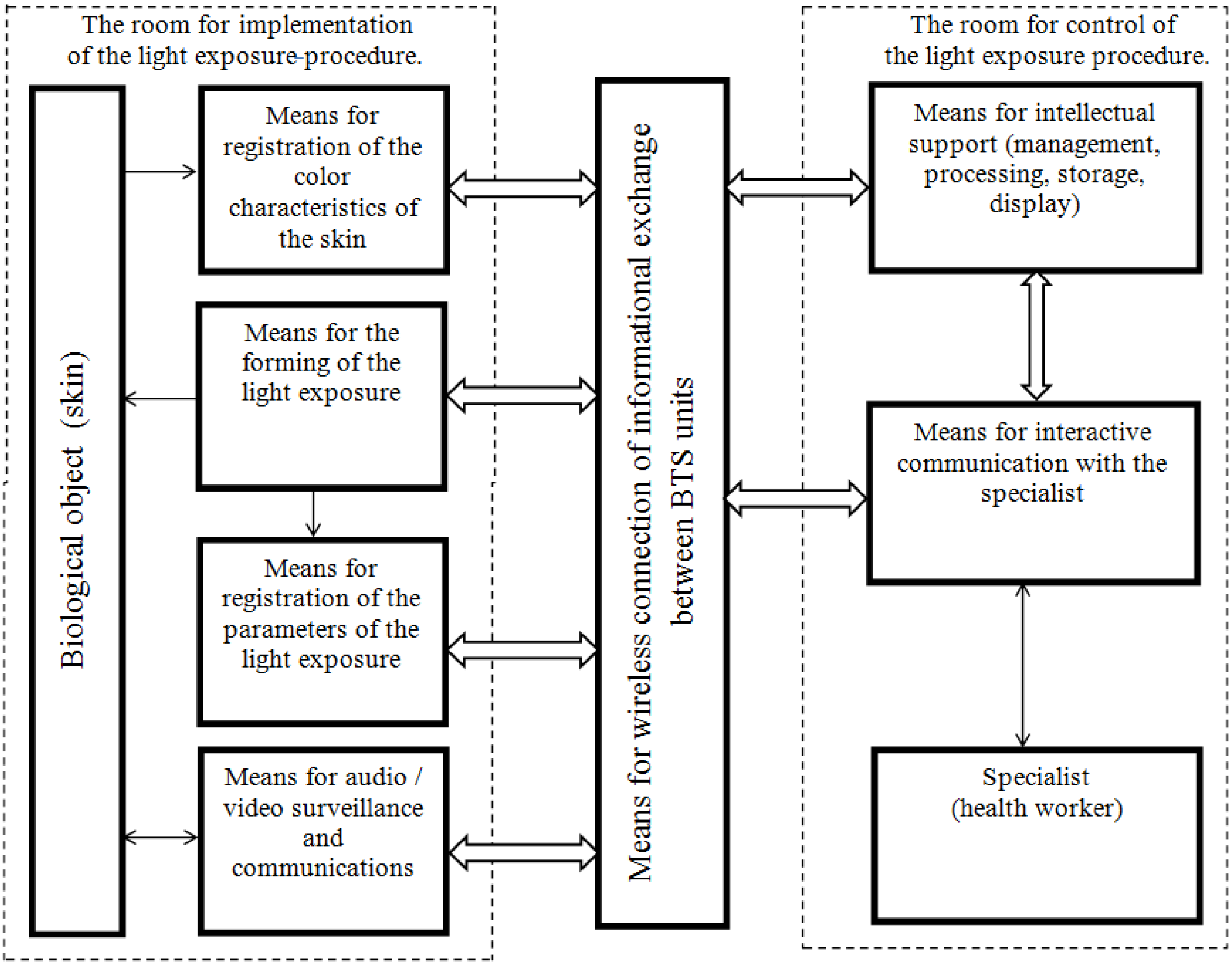

Figure 1: Structure of the biotechnical system of the controlled light exposure on human skin.

In order to ensure ergonomic comfort and safety (in terms of protection from UV exposure) of the specialist, who manages the radiation procedure, all technical means are territorially separated. Some devices, which form and control the light impact on the biological object and register the color characteristics of his skin erythema, are placed in a separate room. In the limited space of the room there are constant conditions which are essential for metrologically correct implementation of the functions. During the implementation of the light exposure procedure, audio/video surveillance of the patient (patient group) is performed.

The room for the integrated control of the radiation procedure is a specialist's (doctor's) office, where it is necessary to install means of informational support of the BTS and interactive communication devices with the specialist (personal computer, laptop, tablet, smartphone).

Combining technical BTS devices located in different areas into a single information space, is provided with a wireless communication line.

The quality of the solution - metered, controlled and safe therapeutic and prophylactic radiation, depends on the level of impact parameters control.

For this purpose, it is proposed to use light-emitting diodes as light flux emitter, which characteristics (spectrum, and its emission intensity) are normalized by manufacturer. The spectrum of the radiation of the majority of LEDs is determined by the technology of their manufacturing and cannot be controlled. So, to obtain the desired range in the emitter, matrix of LEDs should be used, each generating a fixed emission spectrum. To form the required spectral characteristics, the matrix can be selected from the set, radiating infrared, red, green, blue, white and ultraviolet light fluxes.

Means of light exposure parameters control (Fig. 2) controls the radiation intensity that depends nonlinearly on the volume of the current passing through the LED. It should be noted that the threshold and the maximum emission intensity of each LED has an individual variation, so it is better to control the intensity of the radiation individually during the total light flux forming.

Given the fact that the bioobject is the patient's skin, it is necessary to minimize factors that may make uncontrolled changes in the parameters of light exposure (temporary changes is LEDs' characteristics, the separated LEDs and matrix faults, control block errors, and so on). The feedback principle should be used during the forming of the total luminous flux: it means to carry out the evaluation of radiation parameters, compare them with the target settings and implement corrections to the measurement. In this case, the measurement part should be placed on the patient, providing individual approach to the measurement of the luminous flux parameters. The information, formed by the measuring part of the separate devices, must be complemented by a patient identifier and transmitted at the request of the BTS control tools, to address the forming of the parameters of the light exposure in a particular session of radiation.

Selected LED matrix is integrated into the radiating surface, which is structurally designed depending on the purpose (the patient's body part, one patient, set of patients' radiation).

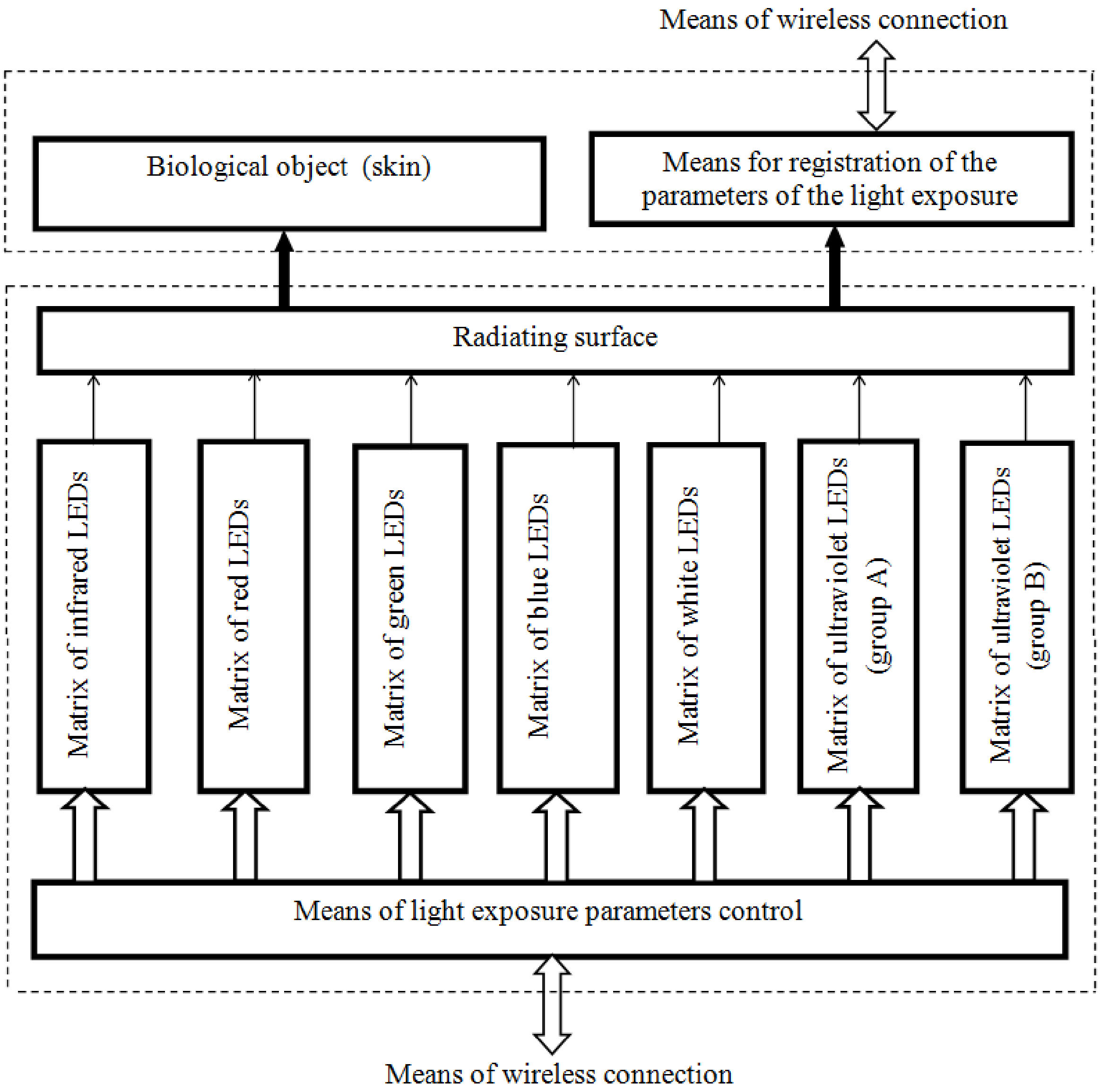

Figure 2: The structure of the means to form the light exposure with controlled spectral characteristic.

DISCUSSION AND RESULTS

Enough developed control process of the light exposure parameters has to be present due to the need to adapt it to the individual perception of the patients' skin (especially the UV part). As a marker of skin perception of UV radiation, it is proposed to use the assessment of changes in the color characteristics of the skin erythema [12]. This assessment in BTS is carried out by means of registration and evaluation of skin erythema characteristics of each of the patients' set before prescribing radiation sessions.

The first stage of this assessment includes the patient's skin phototype classification (Fig. 3). For this, by means of the light exposure forming, it is proposed to set the luminous flux of the visible part of the spectrum only, with constant parameters, that do not change during the BTS with the particular patient. Registration and converting the reflected from the bioobject light flux into a spectrogram is carried out by means of registration of the color characteristics of the skin (spectrograph).

The information is transmitted into the information control tools, which carry out an assessment of individual properties of skin erythema. The evaluation result, characterizing the initial (prior to radiation session) condition of the skin erythema - S0, is compared with the information generated by the expert.

S - value of the evaluation marker of color characteristics of the skin erythema; Dmax - predicted value of the maximum permissible dose of radiation.

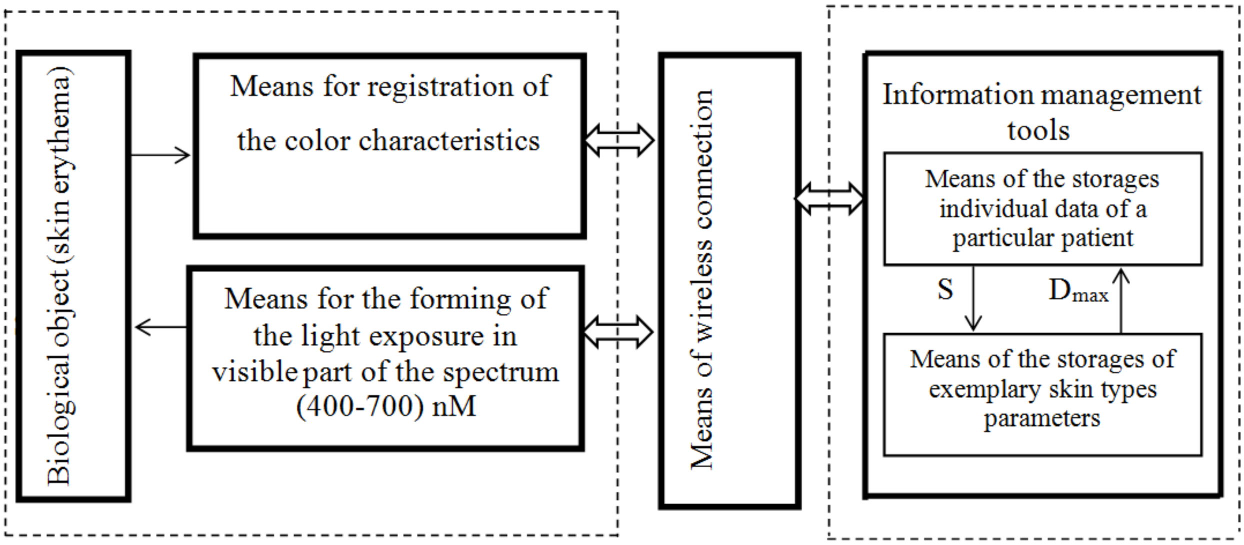

Figure 3: The structure of the means of skin types classification.

The expert information includes the initial (pre-exposure) values of erythema assessment, typical for different skin types. This information is available in the storages of exemplary skin types parameters. The result of this classification is the assignment of the patient's skin to one of the model. Each exemplary skin type corresponds to the maximum permissible dose of UV radiation (Dmax), which is passed to the storage that contains individual data of a particular patient.

At the second stage_of evaluation, in order to justify the results of the classification of skin types, it is essential to obtain experimental data (Fig. 4) to build a mathematical model of the individual properties of the skin erythema according to the method proposed in [13]. The value Dmax, selected as a result of classification, is considered to be safe to form a set of UV effects on the selected skin areas of the biological object (1,2, ... n) in order to obtain a family of dependencies of evaluating marker values of skin erythema color characteristics - S of Di - radiation dose (S = f (Di) = f (E, Ti)), which is formed by varying the two exposure parameters - Ti radiation time and intensity - E.

The third stage consists of registration the color changes of the skin erythema of the given family S = f (D), which is carried out under conditions identical to the first stage (Fig. 3) and is implemented after a latent period required to complete the forming of the color characteristics of erythema [11]. The information is passed to the individual properties of skin erythema assessment tools.

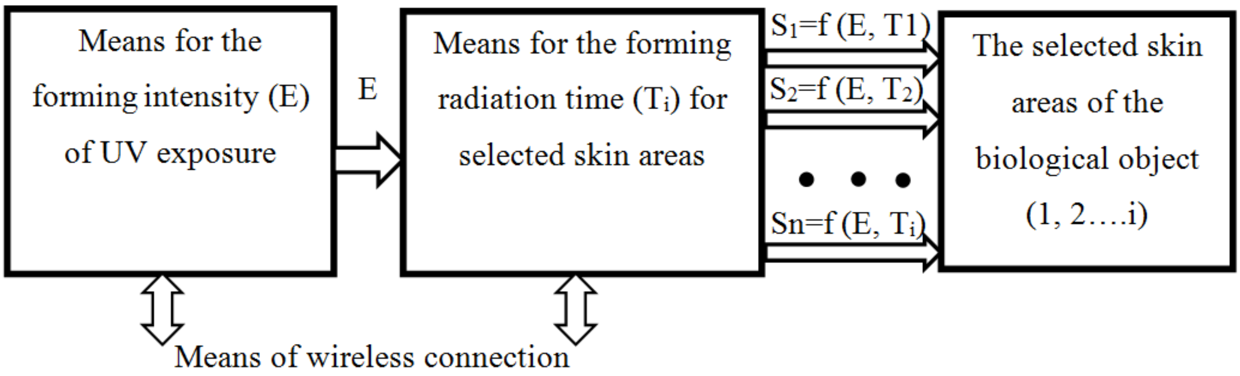

Figure 4: The structure of the tools used to get the family of dependencies of S – Skin color characteristics evaluation marker values from D-erythema dose of UV radiation.

The fourth stage includes the development of a mathematical model for the individual properties of the skin erythema [12, 13], which is carried out using a standard statistical processing software package (e.g., ”Statistica,ver.7.0”), placed in the master devise of the BTS. The model parameters are transferred to the relevant section of individual data storage of the particular patient and are used by the light exposure control unit to predict the safe dose of radiation and to form the corresponding amplitude (E) and time (T) parameters of the personal UV exposure.

In order to coordinate all the elements of the BTS in the implementation of the target function, it is essential to use means of intellectual support (BTS master device), which are based on modern computing facilities [14].

The BTS master device provides:

- reception and storage of exposure process and biological object data from the specialist (doctor);
- identification of the patient involved in the process of radiation;
- control of light exposure parameters in accordance with the given algorithms;
- reception, storage and evaluation of recorded data on the proposed decision rule;
- provision of information on the current state of the radiation procedure for the specialist ;
- acceptance of BTS functioning correction commands from the specialist, when necessary;
- control of situations of BTS devices malfunction and threatening the patient's health;
- switching the alarm in case of alert or emergency;
- forming the protocol of data and events taking place during the radiation session;
- correction of the patient's individual database, when necessary;
- output of the BTS functioning protocol upon completion of the radiation session.

The BTS master device is territorially located in the room for radiation control procedure. The master device is functioning in automatic mode, but is controlled by a specialist (doctor) using standard interactive means of communication (monitor, keyboard, mouse, microphone, web-camera), providing user-friendly interface during the interaction with the working BTS.

All devices of the BTS form a unified hardware and information space. The single informational space is created by uniting the systems and the devices with a communication bus, which forms a local area network (LAN). This LAN master device is presented by the BTS control devices (BTS master unit) located in the specialist's room. Slave LAN devices are located in the room for the radiation procedure. Physically, the informational space is formed by the virtual line (for example, wireless connection with WiFi communication protocol type), supported by advanced computing facilities.

At all stages of operation of the BTS, the specialist can intervene in the process of performing the given tasks. Decision on correcting the BTS workflow is based on the analysis of the original and current information about the condition of the BTS and biological object devices. Information is provided to the specialist in a readable form on the screen of the interactive communication devices.

Alarm devices, located separately, alert the specialist in case of BTS devices failure and situations threatening the patient's health.

If necessary, the information from the individual patients' database can be provided to the specialist in a document (hard copy).

CONCLUSION

The necessity of solving the problem of "light starvation" of various groups and professional societies was shown. The possibility of compensation for light and energy losses by radiation of human skin using artificial sources was studied. The need for secure (metered and controlled) exposure, particularly in the ultraviolet range, is highlighted. It is proposed to use the principle of the biotechnical systems design that combines biological objects and modern technologies into a single control loop to create technical means of adequate exposure for optimum solution of the target problem. A generalized structure of the biotechnology system is developed. The features of the organization of its separate elements are shown. It is proposed to use modern technologies to create means of intellectual support of the biotechnical complex. The possibility of modifying and improving the biotechnical system in accordance with the specific requirements of the light radiation procedure is studied. Possible improvements of the level of comfort and safety of biological object under radiation due to the introduction of the state of the human body and the environment monitoring procedures are suggested. The ways to improve the control of the light corrective action by increasing the number of simultaneously radiated patients and by attracting additional information about the changes in the human body caused by light radiation (for example, changes in the biochemical, biophysical and physiological levels) are shown.

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