Possibilities of Using Dynamically Controlled Semiconductor Light Sources During Surgical Operations

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***Abstract*— Determination of optimal lighting conditions for contrast imaging of operated objects is important for the surgeon. In this paper, we consider various parameters of a controlled color-dynamic surgical light based on a powerful LED when contrasting individual organs and tissues of model animals. The obtained results will allow to develop a library of color gamut and illumination settings for a wide range of surgical operations.**

Keywords*— Surgical light, controlled semiconductor light sources, Imaging systems, Light emitting diodes, Light sources and illumination, contrast visualization of biological tissues, surgical operations.

I. Introduction

In clinical practice, obtaining sufficient and correct lighting from the point of view of color in the operating room is important, as this affects the successful implementation of the operational aid. Good color rendition is vital in order to clearly define the different shapes, sizes and texture of three-dimensional objects and allow the surgeon to avoid mistakes during the execution of surgery. [1-3].

Good illumination of the operating field, including deep surgical wounds, allows to correctly recognize the change in color in oxygen-containing blood for the determination of cyanosis [4], it is better to differentiate normal and inflamed tissues [5], to assess visually the viability of tissues during transplantation [6]. Poor light conditions in combination with high visual load can cause visual and general fatigue of the doctor, promote the development of myopia, nystagmus and some other diseases, as well as injuries [7-9]. Lighting affects not only the functioning of the visual apparatus, that is, it determines the visual performance, but also on the human psyche, its emotional state. Long stay in conditions of visual discomfort leads to distraction of attention, reduction of concentration, visual and general fatigue, incorrect perception of the state of organs and tissues.

Currently, in practical medicine for lighting operating rooms mainly sources of artificial lighting based on incandescent, halogen and xenon lamps are used. Recently, many leading manufacturers of surgical lighting have begun to produce LED operating lights. Their main advantages are long service life, low power consumption, small size for building compact lighting system designs. The most important advantage of LED lighting from the medical point of view is that they operate at extremely low temperatures in comparison with halogen light sources, which means greater comfort for the surgeon and the absence of UV irradiation causing drying of the open tissue. However, in order to improve the visualization of the operating field, the contrast of perception of various biological tissues, it is necessary to develop an LED surgical light with controllable color parameters for operating field illumination and separate regimens to improve the visibility of various tissues during system operations (abdominal, thoracic, orthopedic,). The combination of colors aimed at improving the visualization and detailing of specific anatomical structures allows to optimize the lighting of the operating field in relation to a certain anatomical area and provides excellent clarity and better perception of the surgical field by the surgeon.

The aim of this work was to conduct preliminary studies of the spectral and color indices of combined LED radiation to increase the contrast of biological tissues, with the possibility of selecting the optimal lighting characteristics for laboratory investigations and surgical operations.

II. Matherials and Methods

Experimental measurements were carried out using a specially designed controlled color-dynamic surgical light based on the powerful RGBW LED Phlatlinght CBM-360 Luminus Inc. The main nodes of the prototype are collected by Submicron Heterostructures for Microelectronics, Research & Engineering Center, Russian Academy of Science (St.

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Petersburg). The prototype of the color-dynamic surgical light has the following characteristics: the output luminous flux up to 4000 lm, the illumination of the area 200x200 mm up to 25000 lx (in white light), with uniform color distribution ~ 5% and intensity not worse than 15%; the area of synthesized colors is more than 75% of the locus of real colors according to the chromaticity diagram XYZ MCE 1931; the number of synthesized different colors is more than 1,000,000; the range of color temperatures for white light is 2500-1200K with a color rendering index of 70-90. One of the elements of surgical light is the output optical system, which allows to perform an effective shift of radiation of different colors from discrete sources and to form a homogeneous intensity and color illuminating zone. The software of this luminaire allows changing the intensity of four types of LEDs: cold white (5000 K), red (630 nm), blue (460 nm) and green (520 nm). Management of light parameters of the surgical light during the research was carried out from a remote computer using the developed software associated with the illuminator over the radio interface Bluetooth class 2 with a range of up to 30 m.

In laboratory conditions, on the basis of State Federal-Funded Educational Institution of Higher Education "Orel State University named after I.S. Turgenev", with the help of a surgical light, animal studies were carried out. Experimental studies were performed on clinically healthy male rats n = 5 of the Wistar line (6 months old) in accordance with the principles of good laboratory practice of GLP (according to GOST 33647-2015). The work was approved by the ethical committee of"Orel State University named after I.S. Turgenev" (protocol No. 10 of October 16, 2017). The animals were kept in controlled quarantine, temperature, humidity, and purity conditions for 2 weeks. During the study, the rats were anesthetized with Zolilet 100 (Vibrac, France), respectively, at standard dosages.

Biological objects were placed on a special fixing platform. Studies were carried out on the skin area after preliminary depilation, subcutaneous fat, muscle tissues of the abdominal cavity organs (intestine, liver). After the end of the study, the animals were withdrawn from the experiment in accordance with the rules for conducting the experiments.

A color-dynamic surgical light was installed above the operating table at a distance of 70 cm, which ensured the creation of a uniform light spot of at least 20x20 cm size (Figure 1). During the research in the software, the parameters of each LED were changed. Based on the subjective visual assessment of the operating team, the optimal illumination of the operating field was selected for each site of the study. The spectral characteristic of the emitted light was controlled by a mobile spectrometer MK350.

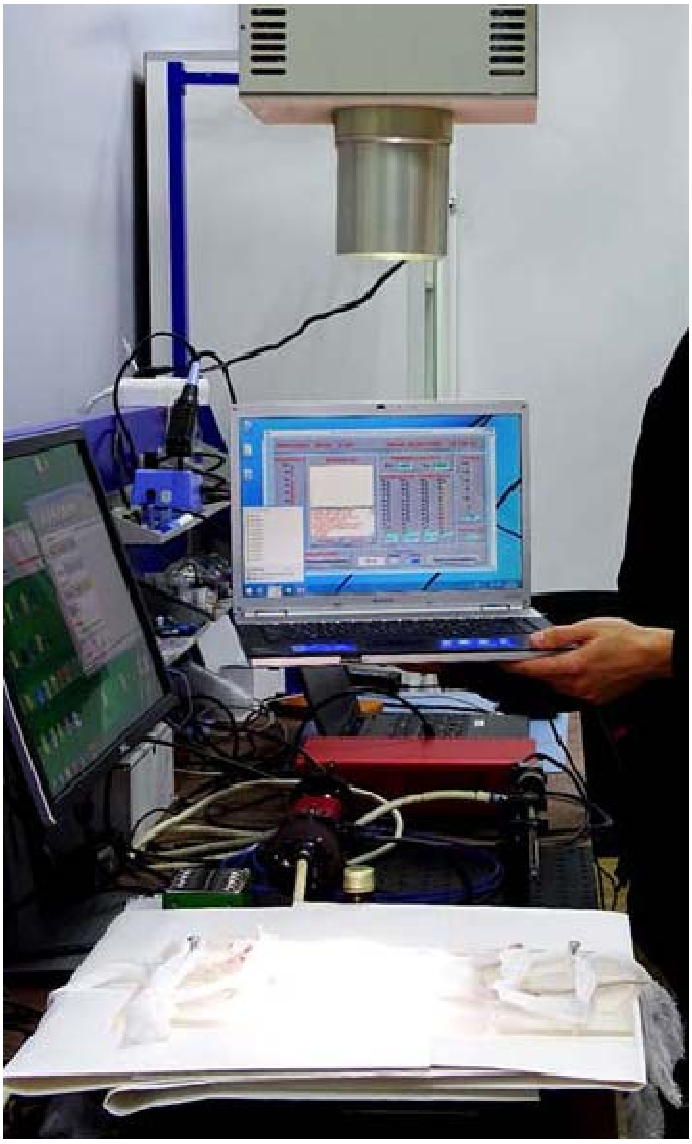

Fig 1. Installation of a color-dynamic surgical light above the operating table.

When each individual organ was illuminated, the spectral components of the light source were changed to increase the contrast of the visualization of the tissue. To select the optimal color of illumination providing contrast imaging, the reflectance spectra R (λ).

III. Results

Figures 2-6 show the results of choosing the most comfortable and contrast lighting of the surgical field when working with different types of tissues and organs.

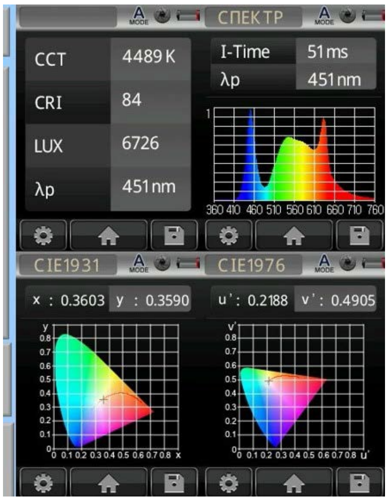

Fig. 2. Color temperature of the light spot when the skin is illuminated.

The parameters in the lamp control program (fig. 2): Intensity 79, Red 9, Green 1, Blue 3, Yellow 99.

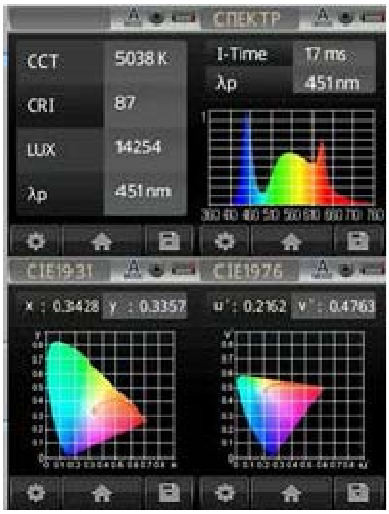

Fig. 3. Color temperature of the light spot when illuminating subcutaneous tissue.

The parameters in the lamp control program (fig. 3): Intensity 76, Red 9, Green 10, Blue 8, Yellow 99.

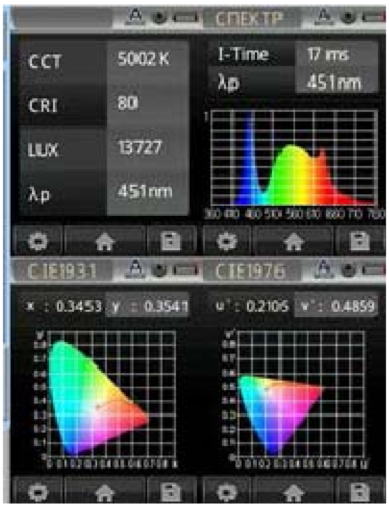

Fig. 4. Color temperature of the light spot when the muscles of the anterior abdominal wall are illuminated.

The parameters in the lamp control program (fig. 4): Intensity 85, Red 4, Green 6, Blue 4, Yellow 99.

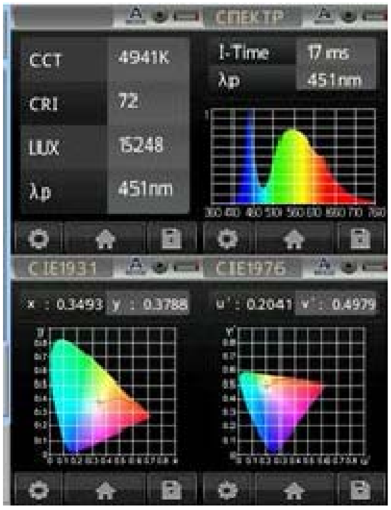

Fig. 5. Color temperature of the light spot when illuminating the serous shell of the intestine.

The parameters in the lamp control program (fig. 5): Intensity 95, Red 2, Green 3, Blue 1, Yellow 95.

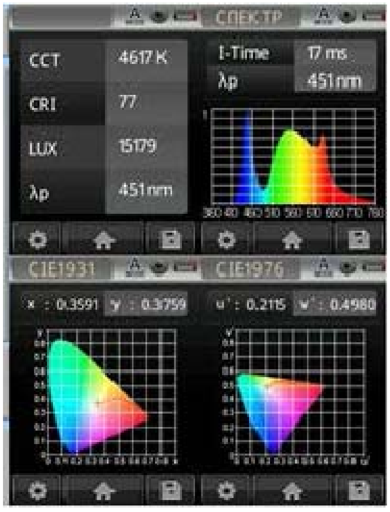

Fig. 6. Color temperature of the light spot when illuminating the serous membrane of the liver

The parameters in the lamp control program (fig. 6): Intensity 95, Red 6, Green 1, Blue 1, Yellow 96.

From the parameters of the program and the data of the spectrometer it follows that a change in the combination of color combinations makes it possible to optimize the visualization and contrast of individual anatomical structures within the subjective assessment of their condition and the differentiation of individual organs and tissues. As one can see, the intensity parameters of the red LEDs for the skin and subcutaneous tissue are different from the rest of the tissue group, which is related to the biological characteristics of the investigated areas.

In general, the spectral evaluation of the operating field is subjective in view of the fact that the assessment of illumination in the visualization of biological tissues is due to the individual features of the visual perception of the surgeon. The results of preliminary studies allow us to draw conclusions about the advisability of using a surgical light with dynamically controlled light and color parameters to achieve maximum resolution and optimal contrast imaging of individual anatomical structures and tissues during surgical manipulations.

IV. Consclusion

The results of this work show that the use of dynamic control of light and color parameters of the illumination of the operating field has the potential for contrasting visualization and a differential approach to the illumination of specific anatomical structures in the course of surgical manipulations.

At present, data are being collected on an extended range of biological objects, including in vivo, in order to develop optimal operating illumination algorithms for surgical interventions on various organ systems. However, it is assumed that the visualization of anatomical structures is influenced by a number of factors, such as the state and type of changes in tissues, the phase development of pathological processes, their reaction to ongoing treatment, blood filling of the tissue, the presence of other liquids, etc. There is a need to conduct studies to study the contribution of each factor to the visualization of biological tissues for a correct interpretation of the intraoperative situation and further development of this direction within the framework of the concept of "Optical Imaging".

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